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NO. 3

FOR PERIOD ENDING

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO SPACECRAFT PROJECT

STATUS REPORT NO. 3

FOR

PERIOD ENDING MARCH 31, 1963

by Manned Spacecraft Center

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FOREWORD

This report is the third in a series of reports on the status of the Apollo Spacecraft Project for the Manned Lunar Landing Program. The first status report described the functions and requirements of the spacecraft modules and systems as well as their development status through September 30, 1962. This report reflects activities and changes in status during the first quarter of 1963.

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SUMMARY

The spacecraft and launch vehicle, being developed by the Manned Spacecraft Center (MSC) and George C. Marshall Space Flight Center (MSFC), respectively, comprise the Apollo Space Vehicle (fig. 1). The configuration of the Apollo spacecraft is shown in figure 2.

The spacecraft is composed of separable modules including a Command Module which houses the crew from the earth to the vicinity of the moon and the return to the earth; a Service Module which contains propulsion and other systems; and a Lunar Excursion Module which separates from the Command and Service Modules when in lunar orbit and descends to the lunar surface for manned exploration.

The Saturn V will be the basic launch vehicle for lunar missions. The Saturn V consists of three stages, the S-IC, S-II, and S-IVB. The S-IC uses LOX-RP-1 propellants and five F-1 engines. The S-II stage uses LOX-LH_2 propellants and five J-2 engines. The S-IVB stages uses LOX-LH_2 propellants and one J-2 engine.

Major accomplishments of the Apollo Spacecraft Project during this reporting period have been:

a. Grumman Aircraft Engineering Corporation was authorized to proceed with development of the Lunar Excursion Module on January 14, 1963. The contract was awarded on March 7, 1963. Contract negotiations were initiated by Grumman Aircraft Engineering Corporation in February and March 1963, for four major subcontracts on the Lunar Excursion Module.

b. Formal negotiations began in January 1963, with North American Aviation, Inc., Space and Information Systems Division to formalize the contract to develop the Command and Service Modules. Negotiations will be completed in early April 1963.

c. Contract negotiations were completed with all of Massachusetts Institute of Technology's Industrial Support contractors, except one.

d. The first Apollo Boilerplate Spacecraft has been manufactured and systems assembly is underway.

e. Manufacture of the first Little Joe II Launch Vehicle has been completed and the Launch Vehicle is now in final assembly at General Dynamics/Convair.

f. The Command Module structural design has been completed on schedule.

[redacted]

MISSION PLAN

The mission objective of Project Apollo is the landing of men on the lunar surface, limited observation and exploration of the lunar surface by the crew, and return of the crew to the earth.

The second version of the Project Apollo Lunar Landing Mission Design Plan (ref. 1) was prepared during this quarter and will be distributed in early April 1963. In addition to including the recent developments in the mission plan, the second version also reflects a change of emphasis from early lunar landing mission profiles to profiles which will require maximum spacecraft performance flexibility consistent with reasonable requirements anticipated for all Apollo missions.

Major developments during this quarter in the trajectory analysis area include:

a. Several of the major trajectory simulations which were being developed during the last quarter of 1962, have become operational. As a result, the ability to generate numbers of mission element trade-off studies, to develop reference trajectories and to analyze alternate and abort trajectory profiles has been greatly improved. Reference trajectories satisfying the mission ground rules specified in the Lunar Landing Mission Design Plan have been developed and published by both North American Aviation, Inc., and MSC.

b. Impulse requirements to be used in designing the Lunar Excursion Module propulsion tanks have been more thoroughly analyzed by both MSC and Grumman Aircraft Engineering Corporation. Mission flexibility trade-off studies are currently underway with an Grumman Aircraft Engineering Corporation-MSC agreement and a joint publication of a more detailed Δ V budget expected during the next quarter.

c. Analysis of alternate and abort trajectories has continued. Particular emphasis has been on the portion of the lunar landing mission between launch escape system jettisoning and injection into lunar orbit. Firm mission design requirements imposed by aborts during this portion of the mission are expected during the next quarter.

Major developments during this quarter in the area of spacecraft contingency operations include:

a. Spacecraft component-failure effects analysis is continuing. Although the particular emphasis is on the design of a malfunction detection system, the results of these analyses are also to be used in determining the best course of action following a contingency. Results of the Saturn I Launch Vehicle-failure effects-analysis were obtained during this quarter. Preliminary results of the spacecraft-modules failure-effects analysis are expected during the next quarter.

b. An analysis of spacecraft and flight crew contingency operations which are required following a spacecraft malfunction will be performed in the near future. The framework of a logic diagram to be used for "bookkeeping" during this analysis has been developed. Every conceivable contingency is being analyzed to determine the adequacy of the spacecraft design to continue on with the normal mission, or continue on an alternate mission, or abort and return to the earth.

SPACECRAFT AND ADAPTER DESIGN AND DEVELOPMENT

The Apollo Spacecraft is composed of a Command Module, Service Module, and a Lunar Excursion Module. An adapter provides the attachment between the launch vehicle and the spacecraft. The Lunar Excursion Module is housed within this adapter during launch.

North American Aviation, Inc., Space and Information Systems Division, is the prime contractor for development of the Command and Service Modules, adapter, associated Ground Support Equipment (GSE), and spacecraft integration. The two major associate contractors are Massachusetts Institute of Technology Instrumentation Laboratory for development of the Guidance and Navigation System and Grumman Aircraft Engineering Corporation for development of the Lunar Excursion Module.

COMMAND AND SERVICE MODULES

The Command Module is the Space Vehicle command-center from which all crew-initiated control functions are performed during the launch, translunar, transearth, earth reentry and landing phases of the mission.

The Service Module is unmanned and contains the propulsion systems for midcourse correction, entry into and exit from lunar orbit, and for lunar orbit rendezvous as a backup to the Lunar Excursion Module propulsion. The Service Module is non-recoverable and will be jettisoned prior to earth reentry.

Launch Escape System

Four successful firings of the launch escape motor were conducted during this reporting period, bringing the total to six successful firings to date. With the exception of the ignition times, all performance parameters have been within specification. The specification ignition time is 0.085 ±0.015 second and the results of the first five tests ranged from 0.098 to 0.152 second. In the sixth test, a nozzle was added to the pyrogen igniter to increase igniter mass flow. The resulting ignition time was 0.082 second, which is well within tolerance. The motor for Boilerplate 6 (BP-6) has been delivered to White Sands Missile Range. BP-6 will be used for the first flight qualification test of the launch escape system in mid-May 1963. A spare motor is scheduled for delivery to White Sands Missile Range on April 15, 1963.

Two successful firings of the pitch-control motor of the launch escape system were conducted during this period, bringing the total to six successful firings of this motor as of March 31, 1963. No problems have occurred. The pitch-control motor for BP-6 and a spare motor are currently scheduled for delivery to White Sands Missile Range by April 15, 1963. A delay in the delivery has occurred due to changing the motor's required total impulse from 1550 to 1700 pound-seconds.

Thirteen development firings of the tower-jettison motor have been completed. During the last test, a graphite-nozzle insert blew out. The failure was caused by a combination of factors which were precipitated by the tearing out of the aluminum nozzle-closure disk rather than the disk breaking at the scored area as designed. The aluminum closure is being replaced by a foam closure similar to that used in the launch escape motor. In addition, the steel nozzle body is being redesigned to provide more bearing area for the graphite insert which will raise the compressive strength safety-factor to greater than 1.9. The motor for BP-6 is being modified at Thiokol Chemical Corp., and is scheduled for delivery to White Sands Missile Range by April 15, 1963.

The escape tower design has been established as a 10-foot titanium structure. Fabrication of the first and second towers has been completed. The first tower was used on BP-19 for parachute recovery testing and the second tower will be used on BP-6 for the PA-1 test.

The explosive-bolt tower release system is also scheduled for use on BP-6. Exploding bridgewire initiators for ignition of the rocket motors are being replaced by Apollo-standard hotwire initiators on motors for use on the spacecraft following Boilerplate 6.

A common standard electro-explosive initiator philosophy has been adopted for the Apollo Spacecraft. This will be a hotwire (resistance type) device having two firing circuits, each with a single bridgewire, which will meet AFMTC-RF safety no-fire requirements of 1 amp or 1 watt for five minutes through both bridgewires simultaneously. All-fire current of 3.5 amp and operating temperature limits of -200°F to +300°F have been specified; a bayonet-type electrical connector will be used. For safety in storage, handling, and installation, a shorted mating electrical connector will be required instead of the usual clip or spring type, thus providing protection against damage to pins. Parallel development programs are underway with qualification scheduled to be completed in June. One of two devices will be selected as the Apollo standard. This initiator will be used throughout the spacecraft to convert electrical energy to explosive energy. The initiator will be sealed at the factory into pressure cartridges, detonators and ignition cartridges; and also will be used as a pressure device (without boosting) in appropriate applications, such as small explosive switches and valves.

Command Module Structural System

The 100 percent release of structural design drawings for the Command Module was accomplished during January 1963, as scheduled.

The heat shield support stringers have been redesigned to allow radial contraction of the heat shield with respect to the inner structure. This redesign was dictated by the thermal stresses which will be induced during the cold soak phase of the flight.

The study conducted by North American Aviation, Inc., and MSC on an alternate ablative heat shield was completed on February 7, 1963, with inconclusive results on the thermo-structural aspects of the design. A follow-on study was authorized in which North American Aviation, Inc., will evaluate the three most promising candidate materials, Avcoat 5026, Emerson T-500, and Dow Corning 325, for mechanical and thermostructural properties. This follow-on study is to be completed during June 1963, and should provide sufficient data to enable a first-order assessment of the feasibility of an elastomeric ablator heat shield.

The mechanical cable release system for the Command Module-Service Module separation has been replaced by three linear-shaped charges which cut tension ties (metal plates) between the modules. Each cutter consists of two linear-shaped charges (100 gr/ft $\times$ $3\frac{1}{2}$ inch) detonated by Apollo standard detonators.

Service Module Structural System

The 100 percent release of structural design drawings for the Service Module is scheduled for May 1963.

Venting requirements for the Service Module and adapter have been coordinated with MSFC for launch vehicles SA-6 thru SA-111. The venting scheme will be finalized by April 15, 1963.

Project Apollo Dynamic Test No. 1 (BP-9) was started at MSC on March 20 and completed on March 31, 1963. Frequency scanning was conducted through the range of 20 to 450 cps. Eighteen distinct modes between 46 and 301 cps were mapped. Damping was determined for each mode by at least one method. The test results will be used to review the adequacy of the instrumentation on BP-13 (SA-6) and to aid in evaluation of flight data. BP-9 will be shipped to MSFC so as to arrive there on April 8, 1963.

Crew Equipment

A revised seat angle is under consideration which will provide a more physiologically acceptable load factor orientation during reentry and abort. The change will affect impact stroke volume, panel reach, and other aspects of cabin arrangement.

In order to eliminate much of the present couch complexity, North American Aviation, Inc., has proposed the following design criteria for couch adjustment:

a. Removable calf pads for thigh sizing.

b. Movable head pad for torso length adjustment.

c. Deletion of neck angle adjustment.

d. 66° hip angle during reentry and landing.

e. 108° hip angle during launch.

f. Arm angle and length adjustments.

g. Food support adjustments.

This proposal is under study by MSC; final approval is pending a mock-up evaluation in mid-may 1963.

North American Aviation, Inc., and Minneapolis-Honeywell Regulator Co., presented the design concepts for the translational and rotational hand controllers. Both controllers had the principle operating axis parallel to the forearm. This design was considered unsuitable for the rotational controller, and North American Aviation, Inc., was directed to reorient the axis normal to the forearm. The controller motions will be as shown in Tables I and II.

TABLE I.- TRANSLATIONAL CONTROLLER MOTIONS

S/C Movement	Controller Movement
Fore-Aft	Fore-Aft
Up-Down	Up-Down
Left-Right	Left-Right
SPS Engine Off	Rotate Clockwise

TABLE II.- ROTATIONAL CONTROLLER MOTIONS

S/C Movement	Controller Movement
Pitch Up-Down	Rotate Aft-Forward
Roll Left-Right	Rotate Left-Right
Yaw Left-Right	Rotate Counterclockwise & Clockwise

The center of rotation for the translational controller is approximately four inches forward of the hand. The centers of rotation for the attitude controller are below the hand for roll control, within the hand for yaw control, and at the center of the palm for pitch control.

Recessed toggle switch and rotary switch controls will be used on the main panel, rather than the rocker switches shown in Mock-up 18. Crew Safety System displays for the Saturn I configuration have been given to North American Aviation, Inc. MSFC will provide all the signals to the instruments. These displays are located just to the left of the Flight Attitude Indicator. The Integrated Display and Data Viewer proposed by North American Aviation, Inc., has been deleted from the main panel. The panel has been reconfigured to reflect this deletion and other changes in the couch-back angle.

North American Aviation, Inc's., recommendation for ten 28-volt d-c floodlights has been accepted. The use of 28-volt d-c for integral lighting and indicator lights had been held in abeyance pending their environmental tests of available lamps.

The following post-landing survival equipment will be carried in the Command Module: compass, lighter, fishing kit, nylon cord, whistle, sunglasses, food, knife, medical kit, water containers, signal mirror, dye marker, desalter, flashing light, and beacon. A reduction in the amount of emergency medical equipment resulted in a weight savings of approximately 12.5 pounds.

North American Aviation, Inc., presented their proposed centrifuge program to MSC. The desired program schedule requires a nine-week session between August 5 and October 4, 1963, and a ten-week session between April 20 and June 26, 1964. The first session will test the panel layout and crew couch concepts; the second session will be a qualification test of prototype hardware and interface. The program was approved in general.

Environmental Control System

After consideration of a proposed change to incorporate a dual-pressure centrifugal-separator system, the wick-type water separation technique was retained due to cost and schedule implications. A wick-type water separator will be sent to the MSC for evaluation of possible wick contamination problems. The effect on the water management system reliability as a result of incorporating a manual backup to the present redundant water delivery pump is being investigated. Other significant changes in the configuration of the water management system include the addition of a separate freon tank for boost cooling and also a reduction of the potable water tank capacity. The combined effect of these changes will be a reduction in system weight and are increased in system reliability.

The Environmental Control System (ECS) breadboard test facility has been approved and will be suitable for manned operation. Integrated ECS breadboard tests will be conducted in this facility beginning in October 1963, with manned testing beginning in January 1964.

An ECS qualification unit will be delivered to the MSC, Houston, after completion of testing at AiResearch Manufacturing Company. This unit is due in April 1964, and will be used by MSC in direct support of Project Apollo operations and final development.

The MSC has established ECS metabolic design criteria for both nominal and emergency modes of operation. The largest revisions were in water requirements, which are: 6.6 lb/man/day for normal operation, 12.4 lb/man/day for emergency operation.

The Apollo Spacecraft gas analyzer will be government furnished equipment R & D instrumentation. North American Aviation, Inc., will procure the CO_2 sensor for the operational spacecraft while taking full cognizance of existing NASA development work plus previous Project GEMINI procurement.

The ECS configuration for Airframe (AFRM) 001, the manned propulsion test vehicle, was established. The atmosphere will be ambient air and a simple suit mode of operation will be furnished. Metabolic and equipment loads will be dissipated normally by ground support equipment (GSE) cooling. Project MERCURY-type suit ventilators will provide backup cooling and a breathing mode for the crew.

The cryogenic supply subcontractor, Beech Aircraft Company, cancelled Hamilton-Standard as a sub-tier supplier of the cryogenic supply valve packages. Effective March 7, 1963, Parker Aircraft became the new supplier and has demonstrated excellent progress to date.

Navigation and Guidance System

MSC contract negotiations have been completed with all Massachusetts Institute of Technology Industrial Support Contractors, except A. C. Spark Plug whose contract will cover the Inertial Reference Integrated Gyro. Negotiations on this contract are continuing and should be completed during the next reporting period. However, negotiations with A. C. Spark Plug for the System Assembly and test contract were completed on January 25, 1963. The contractual documentation has been prepared for NASA Headquarter's approval.

Negotiations were completed on March 29, 1963, with Kollsman Instrument Corporation for the optical subsystems and contractual documentation is now being prepared. The contract for the Apollo Guidance Computer with Raytheon Company was also approved by NASA Headquarters on February 8, 1963.

During this reporting period, the Guidance and Navigation System hardware manufactured by Industrial Support Contractors of the Massachusetts Institute of Technology includes a breadboard GSE unit to be used in testing the prototype Guidance and Navigation Systems, three 25-Impulse Reference Integrating Gyros (Mod 2), and nine Pulse Integrating Pendulum accelerometers. In addition, two inertial measurement units, built by the Massachusetts Institute of Technology, are undergoing laboratory testing.

[redacted]

A unified power-flight steering law has been developed by Massachusetts Institute of Technology. Initial studies indicate that this steering could be used during translunar injection, lunar orbit insertion and transearth injection.

Eight guidance and navigation functions are shown in Table III. Some of the functions have been programed, and some are estimated. The minimum estimate uses 8848 words and the maximum uses 12,240.

There is a 48 to 3440 word margin below the maximum capacity of 12,288 words of fixed memory. Table III presents the detailed program status of the computer program. Procurement has been initiated for micrologic units to be incorporated into the computer.

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TABLE III.- COMMAND MODULE/SERVICE MODULE GUIDANCE & NAVIGATION
SYSTEM STATUS OF AUTOMATIC GUIDANCE CONTROL

PROGRAM	MAXIMUM ESTIMATED WORDS	MINIMUM ESTIMATED WORDS	REMARKS
Interpreter, control and elementary functions	2850	2500	More powerful language in which multiple-precision vector and scaler manipulations can be written compactly; Trigometric Functions, log and exponential; input-output routines.
Checkout and error	1000	400	Automatic Guidance Computer self testing and checkout, diagnostics, in-flight maintenance, analysis of errors.
Systems checkout	1000	750	PACE (Prelaunch Automatic Checkout Equipment)
Midcourse and near planetary orbit	2500	2000	Position and velocity determination from sightings and velocity corrections.
Alinement	1100	1024	Inertial Measurement Unit alinement prior to lift-off, during planetary orbit and during midcourse.
Reentry	1290	1024	Reentry steering equations and logic for point return.
Display and Control	1500	750	Automatic Guidance Computer displays and keyboard entry processing.
Powered flight	1000	400	Translunar injection, lunar orbit insertion and transearth injection.
	12240	8848	
	48	3440	Margin below capacity.

Stabilization and Control System

Contract negotiations with Minneapolis-Honeywell Regulator Company for the Stabilization and Control System have continued through this reporting period and are expected to be completed by May 1, 1963. The Stabilization and Control System configuration has been firmed into two basic subsystems which will be packaged in thirteen individual components. The subsystems and their components are listed below:

a. Flight Control Subsystem

1. Rate Gyro Package
2. Attitude Gyro, Accelerometer Package
3. Pitch Channel Electronics Control Assembly
4. Roll Channel Electronics Control Assembly
5. Yaw Channel Electronics Control Assembly
6. Auxiliary Electronics Assembly (includes Automatic Guidance Control Unit)
7. Displays, Attitude Gyro Electronics Control Assembly

b. Controls and Displays Subsystem

1. Flight Director Attitude Indicator
2. Gimbal Position Indicator
3. Δ V Display
4. Stabilization and Control System Control Panel
5. Translational Controller
6. Rotational Controller

Eight operational modes have been established for the Stabilization and Control System. These modes are: monitor mode; Guidance & Navigation attitude control mode; Stabilization and Control System attitude control mode, Stabilization and Control System orbit mode, Guidance & Navigation Δ V mode, Stabilization and Control System Δ V mode, Guidance & Navigation entry mode, and Stabilization and Control System entry mode.

The Stabilization and Control System design freeze and also the design specification release date for the system and GSE occurred in January 1963. System procurement specifications were released to Minneapolis-Honeywell Regulator Co., in February 1963. All system block diagrams and switching functions plus a GSE functional mock-up were completed in March 1963.

Three design changes have occurred since that release date. These changes are: (1) the attitude gyros and accelerometer were repackaged into a single unit; (2) the analog portion of the Δ V readout was replaced by a digital readout; and (3) the rotational hand controller is being reconfigured to a upright stick with fore-and-aft motion for pitch, side-to-side motion for roll, and stick-twist for yaw control.

Test of various stabilization and control components are underway. Material tests are 60 percent complete. Various components of the flight control and controls and display subsystems are undergoing temperature and vibration tests. Breadboard tests are 65 percent complete. Entry mode simulation tests and analyses have been completed.

Reaction Control System

The design release of the pressurant and propellant feed systems for both the Command and Service Modules is currently proceeding on schedule. All procurement specifications, with the exception of one, have been released for bid and an engineering evaluation of bids is currently about 60 percent complete. The component subcontract for the positive expulsion tanks has been awarded to Bell Aerosystems Company.

A Service Module Reaction Control System (RCS) engine has demonstrated continuous runs of 600, 625, 1205, and 1412 seconds in combination with pulse mode operation for a total running time of 4380 seconds at a thrust level of 100 pounds ±5 percent without mechanical degradation. Specific impulse ranged from 295 to 303 seconds for steady state runs on this engine.

The Service Module RCS engine propellant valve design has been changed from a 3-coil to a 2-coil solenoid configuration. The minimum impulse bit requirement remains at 0.5 ±0.10 lb/sec, to satisfy the navigation sighting roll rate requirement of 1.2 arc-minutes per second. Limited tests of the 2-coil valve configuration and simplified driver circuitry have shown that the requirement can be met with this design. Prototype engine tests with 2-coil propellant valves are scheduled to begin on April 1, 1963.

The Command Module RCS engine expansion nozzle area ratio has been changed from 40:1 to 10:1 to meet installation requirements and also the revised reentry heat-flux restrictions. The current configuration uses the GEMINI spacecraft injector, combustion chamber ablative billet and throat insert; but a separate nozzle ablative-billet for the Project Apollo requirement for a 10:1 area ratio and ablator interface mounting provisions. Engine operating life, plus steady-state and pulse-mode performance have not yet been demonstrated with the new configuration, but these tests are currently scheduled for completion prior to July 1, 1963. Minimum steady-state impulse for the 10:1 nozzle area ratio is 283 seconds at an altitutde thrust-level of 93 lbs.

Phase I-B of the Service Module RCS Jet Plume Tests at Arnold Engineering Development Center has been delayed by test cell mechanical difficulties in the altitude simulation equipment. Project Apollo test hardware is on hand and installed for the first series of plume impingement tests to begin during the week of March 25, 1963. Initiation of Phase II testing has been delayed some seven weeks due to the above difficulties.

Phase I cold flow breadboard tests of the Command and Service Module pre-prototype systems are 20 percent complete with the static tests near completion. During static tests, pre-prototype positive expulsion tanks have consistently demonstrated 98 percent or better expulsion efficiency. Dynamic coldflow tests are scheduled for initiation on May 1, 1963.

The current design of the pyrotechnic-actuated pressurant and propellant valves in the Command Module RCS system incorporates the Project Apollo-standard initiators.

Service Module Propulsion System

The subscale Project Apollo engine test program at the Arnold Engineering Development Center was completed on February 1, 1963. This testing revealed two major areas of concern in developing the full-scale Service Module rocket engine. These areas were:

a. The inability of an all-titanium nozzle extension to withstand thermal stresses at attachment area ratios smaller than 10:1.

b. The apparent limitation on maximum obtainable thrust chamber specific impulse due to the recombination effect present in low pressure, N_2O_4 - 50/50 UDMH/N_2H_4 rocket engines.

To correct the nozzle extension deficiency, the development program was revised to concentrate on a columbium/titanium nozzle extension and an improved attachment flange design.

To fully evaluate the performance limitation possibility, sea level testing was initiated to accurately determine injector c*[1] values which would allow precise differentiation between injector/chamber performance and nozzle performance during simulated altitude testing at Arnold Engineering Development Center.

Full-scale aluminum injector testing resulted in the evaluation of seven unbaffled injector patterns and seven baffled patterns. Four unbaffled and three baffled patterns were dropped from further consideration because of low performance, inherent instability, or poor ablative chamber compatibility. Fabrication difficulties were experienced in brazing the injector components, drilling the face patterns, and welding the baffle structure. The use of new brazing techniques, the selection of new welding rods, and the use of a tape-controlled automatic drilling machine largely overcame these difficulties.

The service life requirement for the Service Module Propulsion System was determined to be 720 hours minimum. This is the total "wet" time for the system including all test time and 336 hours of flight time. Allison Division of General Motors was awarded a contract for the fabrication of the Service Module Propulsion System propellant tanks and Airite Products of Los Angeles was awarded a contract for the fabrication of the Service Module Propulsion System helium bottles. North American Aviation Inc., has done considerable study and testing to determine the compatibility of 6AL-4V Ti with N_2O_4 and Aerozine 50. Tests to date indicate complete compatibility with Aerozine 50 and only slight reaction under certain conditions with N_2O_4. Test Fixture F-3 was completed and delivered to North American Aviation Inc., - Downey for cold flow tests which are scheduled to begin April 1963. Helium solubility tests by North American Aviation Inc., resulted in no effect on the design of the pressurization system. Test data indicated little more than one pound of helium would be dissolved during the systems operation and this will have a negligible effect on the system.

Communications System

The pulse code modulation telemetry bit rate has been changed from 32,000 to 51,200 information bits per-second with the associated format of 128 words per-prime-frame scanned at the rate of 50 prime frames per-second. In addition, the range of the low-level multiplexer has been changed from 0-250 millivolts to 0-40 millivolts which reduces the low-level signal conditioning requirements.

[1] Editor's Note: C*= Characteristic velocity. Measurements of combustion performance which indicate how many pounds-per-second of propellant must be burned to maintain chamber pressure.

Because of the Lunar Excursion Module docking mechanical interference problems associated with the VHF/S-band omnidirectional antenna and its apex radome, all design and procurement associated with the apex mounted omni antenna has been discontinued. Preliminary studies of antennas mounted in the spacecraft strakes are promising.

A digital up-date system requirement has been added to the Command Module communication system. To reduce the effort of the Ground Operational Support System (GOSS) implementation, the spacecraft equipment will be compatible with the modulation and encoding techniques being used in the digital command ground station equipment procured for Project GEMINI.

A subcontract has been awarded to Airborne Instrument Laboratories for the recovery antenna system.

North American Aviation Inc., has completed an engineering evaluation of proposals for the S-band high-gain antenna and the operational C-band transponder antenna system and the subcontract will be awarded in the near future.

Operational Instrumentation

Status of various operational instrumentation components is presented below:

a. Specifications have been released for all transducer equipment. The deletion of inflight calibrations is under consideration.

b. Specifications for the tape recorder have been revised to accomodate a 51.2 kbps (kilo-bits per second) pulse code modulator recording requirement. The analog response is being changed to 13 kc. Breadboard testing of the recorder electronics is nearing completion. An increase in recorder volume of approximately 100 cubic inches is under consideration.

c. The central timer equipment contract was awarded to Elgin National Watch Company. The design is underway on the output buffer and comparator circuitry.

d. Development work was initiated on a Type IV Radio Noise Radiation Alert Instrumentation subsystem and a Proton Flux Rate and Proton Directional Detection subsystem. A tentative selection of system suppliers has been made and research has now been initiated in selecting an operating frequency.

e. The weight of the signal conditioner has been reduced to 32.8 pounds from an original estimate of 51 pounds. The majority of the transducer output levels to the signal conditioner is presently 0-5 volts.

Electrical Power System

Analyses of the Command Module and Service Module electrical loads are being conducted at regular intervals. The latest review indicates that the capacity of the fuel cells, batteries, and inverters is adequate for the planned mission phases.

Fuel cell development design was completed in February 1963. Component testing has continued and is ahead of schedule on the single-cell, six-cell, and 31-cell stacks. A 31-cell stack has achieved the best on-loading running time which was 150 hours. However, complete configuration module testing is currently behind schedule.

Solutions are being developed on the two major fuel cell problems which are; effective seals at the junction of the oxygen and hydrogen electrode back-up plates, and an effective load-sharing device. Previous problems in the areas of insufficient electrode deliveries, low bubble pressure and natural frequency of single cells have been solved.

Pyrotechnic batteries will be connected only to firing circuits of Apollo-standard initiators. These batteries cannot be used as power sources for any other device, but can be recharged as necessary. Two pyrotechnic methods of umbilical separation between the Command Module and Service Module have been investigated. Two linear-shaped charges 100 gr/ft × 12 in. were decided upon as opposed to a guillotine design. The charges are located in the Service Module ablative molding which eliminates Command Module-Service Module connector pins and thereby effects a weight savings of 40 pounds.

Earth Landing System

A total of fourteen parachute recovery system tests were conducted at El Centro, California, during this reporting period. There were three drogue parachute tests, one single main parachute test, six two-cluster main parachute tests, and four three-cluster main parachute tests. One three-cluster main parachute test failed to sequence because the parachute test vehicle was not armed prior to the drop.

Two drogue parachute tests at design dynamic pressure were successful and verified predicted drag and canopy stability. A 1.5 design dynamic pressure test with a drogue parachute on March 22, 1963, resulted in damage in two gores. Higher strength horizontal ribbons will be incorporated into the parachute on the next test.

A single parachute ring-sail test, with the suspension lines shortened from 1.4 d_o to 1.0 d_o, was conducted to determine the effects of line length on opening time. The opening time and load differences were not significant.

Cluster test with the original ring-sail design showed unsatisfactory performance in the reefed and opening characteristics. A modification of this parachute, which included an effective porosity decrease in the crown and an individual sail fullness decrease in the skirt, also showed unsatisfactory performance.

A modification of the ring-sail design to include only an effective porosity decrease in the crown (PDS1543) appeared to have corrected the unsatisfactory performance. Four successful two-cluster and one three-cluster bomb configuration drops were made to verify the performance. The sixth drop with this parachute configuration, using the parachute test vehicle, resulted in loads on one parachute being 7,000 pounds higher than expected. The opening of two of the three parachutes required 9 seconds longer than expected. This main parachute configuration is currently being tested at pad abort conditions in support of the PA-1 mission.

Northrop Ventura has complete design and has started manufacturing on the $\frac{1}{2}$-ring-sail, $\frac{1}{2}$-solid and $\frac{1}{2}$-ring-slot configurations, which will be tested on a second priority basis to tests supporting PA-1 mission.

North American Aviation Inc., contracted a solid parachute program to Pioneer Parachute Co. on March 4, 1963. The solid parachute program will consist of seven tests which will be conducted at El Centro, California. The first test is scheduled for the week of April 8, 1963.

The modification of boilerplate 3, Earth Landing System test article, is progressing on schedule for the first C-133A drop on April 12, 1963. The boilerplate will be transported to El Centro, California, on April 5, 1963. Boilerplate 19 is scheduled for shipment four weeks after Boilerplate No. 3 is shipped.

A total of nine impact drop tests were conducted during this reporting period, six on soil and three in water. The first drop from the new North American Aviation Inc., impact facility was conducted March 11, 1963. Results of the impact drops on soil have shown that the accelerations obtained are not compatible with the crew tolerances. North American Aviation Inc., conducted two tests to investigate a 32° spacecraft attitude at impact. Accelerations were within crew tolerances. The 32° impact with expected tumble shows promise for future applications. BP-1 has been modified to better simulate the spacecraft structure for the 32° impact attitude.

The apex heat shield release-and jettison-system have been redesigned. The cable-release system has been replaced by two bolts which are failed by tension, upon the operation of the shield jettison thrusters. Prior to escape-tower jettison, flanges on the heat shield fit between the tower legs and Command Module structure, thereby providing additional support. The shield is no longer thrust into the tower and captured by latches during low altitude abort, as was previously reported, but is always jettisoned after tower jettison which eliminates the mode changes which were previously necessary. Designed shield-separation-velocity has been achieved with the new system during tests with only one of the two thruster-systems operating.

All parachute mortars (1 drogue, 3 main pilot) are operated by electrically-initiated cartridges; redundant cartridges are provided in each mortar. The drogue disconnect has been redesigned using dual linear-shaped charges (25 gr/ft × 2 3/4 inch) which cut a metal plate. The main-parachute riser disconnect has been redesigned to use linear-shaped charges (175 gr/ft × $2\frac{1}{4}$ inch) to cut the risers. All pyrotechnic devices are initiated by means of the Apollo-standard electric hotwire initiator.

ADAPTER

The spacecraft-launch vehicle Saturn I adapter has been redesigned to incorporate the Saturn V load capability. The honeycomb core depth of the adapter has been increased from one inch to two inches as a result of stiffness requirements. This was accomplished without an increase in weight due to a trading-off of facing sheet weight for core weight.

The Saturn V adapter is in the early design stages with several configurations under consideration. Choice of the final configuration is now dependent upon the Lunar Excursion Module landing gear design, which is scheduled to be firm by June 1, 1963.

The separation of the adapter section from the Service Module and launch vehicle, plus the cutting of the adapter section into two parts will be accomplished by dual-initiated, manifolded linear-shaped charges (15 gr/ft). Dual charges which face each other, are currently planned.

LUNAR EXCURSION MODULE

The Lunar Excursion Module serves as a shuttle vehicle for transferring two of the three crew members and their payload from the Command Module in lunar orbit to the lunar surface and then return them to the Command Module. Included in this operation are the functions of separation from the Command Module, lunar descent, lunar landing, ascent, and rendezvous and docking with the Command Module.

Grumman Aircraft Engineering Corporation was authorized to proceed with development of the Lunar Excursion Module on January 14, 1963. Contract award was made on March 7, 1963.

Figure 3 illustrates the Lunar Excursion Module configuration as conceived by Grumman Aircraft Engineering Corp., at the time of their proposal. The configuration features fully-staged propulsion, affixed five-legged landing gear, two docking-hatches with a separable docking module.

The ascent stage includes the crew compartment with a minimum of systems and equipment inside the crew compartment, an equipment compartment housing most of the equipment outside and aft of the crew compartment, and the two docking-hatches. The ascent engine is fixed and a reaction control system is employed for thrust vector, stabilization and control purposes.

The descent stage includes the descent propulsion, landing gear and a minimum of other systems. The descent propulsion features a gimballed engine with six positive-expulsion propellant tanks. The landing gear has as fixed geometry and is configured within an envelope dictated by the adapter—S-IVB stage considerations. Systems and equipments which are clearly not required to be on the ascent stage are on the descent stage.

A separate docking module is provided which incorporates the heavier elements of the docking interface. Further, it provides an opportunity to leave the heavier elements of the docking interface on whichever module is receiving the minimum velocity increment.

Configuration evaluation and discussions were held during the contract negotiations and it was agreed that Grumman Aircraft Engineering Corp., should undertake a study to arrive at a design approach for the Lunar Excursion Module configuration. This study was to be broad in scope with the following priority items to receive emphasis in the first four months; cabin size, distribution of equipment and consumables, fire-in-the-hole, visibility, ingress-egress, docking requirements, tankage sizing, thrust-vector control, and target weights. The study will be completed in April 1963.

Structure and Landing Gear

Preliminary Lunar Excursion Module mounting criteria have been established. Grumman Aircraft Engineering Corp., has studied various Lunar Excursion Module support concepts and made the corresponding schedule considerations. The landing gear configuration design will be firm enough for the adapter and support design to begin by June 1, 1963. For schedule purposes, this will eliminate the S-IVB stage instrument unit as the point of Lunar Excursion Module support. Space envelopes available in the S-IVB stage instrument unit were coordinated with Marshall Space Flight Center. Grumman Aircraft Engineering Corp., is continuing study on the "folded gear-stub" support and the "tension truss" concepts of Lunar Excursion Module support.

Grumman Aircraft Engineering Corp., presented a response-controlled approach to describe the vibration environment expected on the Lunar Excursion Module. These data will provide information for procurement specifications and structural design at an early date. MSC and Grumman Aircraft Engineering Corp., have planned to coordinate with MSFC to obtain additional information on the launch vehicle induced vibration environment.

Meteoroid flux penetration equations and design criteria have been established. These data are being used by Grumman Aircraft Engineering Corp., for weight-versus-reliability studies.

Crew Equipment

Grumman Aircraft Engineering Corp., has completed the initial study phase in an effort to maximize common usage of the Project Apollo Command Module, and Project GEMINI and Project MERCURY controls and display equipment. A tentative list of some 28 common items was established, however, the results also show that this list will probably be expanded. Also, the common use of technology and the early exchange of equipment detail characteristics will expedite the subsequent interfacing activity.

Subsystem controls and display panels have been developed based on current subsystem configurations. Integration into a total panel has not been completed but has taken alternate arrangements in support of the various vehicle configurations under study. Approximately 15-16 square feet of panel area will be required and is available on the vehicle configuration being considered.

Crew member metabolic rates, thermal balance, and water requirements criteria have been established jointly by Grumman Aircraft Engineering Corporation, North American Aviation Inc., and MSC. The criteria will be used for design purposes pending further verification or revisions which will be based on an MSC-conducted test program.

Collection and storage of fecal waste during the Lunar Excursion Module phase of the mission cannot be adequately accomplished with the suit-incorporated system. The Lunar Excursion Module will be equipped for storage of both the empty and used fecal containers. A suit configuration which will be compatible with the use of the containers is now under study.

Stowage of crew equipment items, some of which are used in both Command Module and Lunar Excursion Module (that is, Portable Life Support Systems, suit thermal garment, et cetera) has been defined. The Command Module will provide storage for two Portable Life Support Systems and three pressure suits and thermal garments. Lesser equipment items and consumables will be distributed between modules according to the mission phase requirements.

There are no specific equipment requirements for personal hygiene during the LEM mission (that is razor, dentrifice, deodorant pads, bathing pads, et cetera), however, this area is under investigation by MSC.

Environmental Control System

The Hamilton Standard Division of United Aircraft Corporation was selected by Grumman Aircraft Engineering Corporation to negotiate for the Environmental Control System (ECS) subcontract. Contract negotiations began on March 13, 1963. Award of the contract is anticipated by mid-May 1963.

Both Grumman Aircraft Engineering Corporation and MSC have performed studies on the use of either the Portable Life Support System or Command Module lithium hydroxide canisters for the Lunar Excursion Module carbon dioxide removal system. Preliminary indications are that the use of the Portable Life Support System canister will provide desirable operational flexibility without unduly penalizing the Lunar Excursion Module design.

Navigation and Guidance System

The Navigation and Guidance System provides the guidance for the Lunar Excursion Module from the point of separation from the Command Module while in lunar orbit through the phases of descent, landing, ascent and rendezvous with the Command Module in lunar orbit. The system will be energized while in lunar orbit, the inertial measurement unit (IMU) will then be alined and the system will function until after the lunar landing is completed. Prior to leaving the lunar surface, the system will be reenergized, the IMU alined, and the system will function until rendezvous with the Command Module is complete.

The Lunar Excursion Module guidance and navigation equipment will be identical with the Command Module system insofar as possible. The computer and power servo assembly (PSA) will possibly be repackaged for the Lunar Excursion Module installation, however, they will use module boards identical to those in the Command Module. The Coupling Display Units and IMU will be identical to those used in the Command Module.

A draft of the procurement plan for Lunar Excursion Module guidance and navigation equipment has been completed.

The Lunar Excursion Module radar configuration requirements and basic operating modes for lunar landing and rendezvous were given to Massachusetts Institute of Technology and Grumman Aircraft Engineering Corporation by MSC in March 1963. The altimeter is a three-beam doppler radar having a two-position antenna. Altitude, altitude-rate, and horizontal velocity components are derived independent of the primary Guidance and Navigation System. This information will be available from approximately 20,000 feet until touchdown on the lunar surface.

The rendezvous radar will use a gimballed antenna with freedom of movement in two axes. An associated solid-state transponder will be mounted on the gimballed antenna. Identical radars and transponders will be placed on the Lunar Excursion Module and Service Module so that radar derived information will constantly be available. The radar will be procured by Grumman Aircraft Engineering Corporation to a joint Massachusetts Institute of Technology-Grumman Aircraft Engineering Corporation specification.

The following rendezvous ground-rules affecting propulsion and visibility from a guidance and control standpoint have been established:

a. The capability to rendezvous and hence remove the entire Δ V along the line-of-sight with the main engines or the Reaction Control Systems propulsion should exist.

b. The primary mode of rendezvous should allow for good visibility of the Command and Service Modules while thrusting along the line-of-sight.

c. If the primary mode of rendezvous uses the main engines, the capability of pulsing the main engines should exist. There should be two pairs of RCS engines along the Z-axis capable of 200 seconds of continuous firing, or one pair capable of 400 seconds of continuous firing.

Stabilization and Control System

The Stabilization and Control System of the Lunar Excursion Module provides attitude control and stabilization of the spacecraft and furnishes a means for navigation and guidance of the vehicle. The system accepts attitude information from the primary guidance system as well as commands for initiating on-off operation of the ascent and descent engines and descent engine throttle regulation and reaction control system on and off. The Stabilization and Control System also provides a backup attitude reference and a means of backup guidance.

Manual attitude, translation and descent engine throttle control from the crew. Manual control is augmented by displays which include inertial attitude, attitude errors in three-body axes and angular rates about three-body axes.

The major Stabilization and Control System components are: a body-mounted rate-gyro package containing three orthogonally-mounted rate gyros; a body-mounted attitude reference package; electronics assemblies for backup guidance for control of the reaction control system and the descent engine gimbal or trim system; and astronaut controls and displays. The attitude reference package exists to provide a backup capability only. The rate gyro package will be in use throughout the Lunar Excursion Module phase of the mission to provide rate stabilization.

Manual control of the Lunar Excursion Module is accomplished by a three-axis attitude controller and a three-axis translation controller. The manual descent-engine throttle-controller may be combined with the translation controller, but this problem is at present unresolved.

Other astronaut controls will enable control-mode selection, deadband selection, gain selection and attitude display control. Incremental velocity will be displayed, primarily for a backup mode, from data furnished by an accelerometer mounted in conjunction with the attitude reference package along the vehicle thrust axis. The descent engine gimbal or trim position will also be displayed.

The control system design and conceptual studies are in progress. Flight simulations are currently underway to determine lunar landing and docking characteristics. Lunar Excursion Module descent, and braking, as well as ascent and rendezvous simulations will be initiated during the next reporting period.

A Lunar Excursion Module and Command Module "common usage" study has been completed by Grumman Aircraft Engineering Corporation. The Lunar Excursion Module Stabilization and Control System requirements have not been defined sufficiently to permit a firm common usage decision, however, a number of items appear to have a potential application. Such items are the rate gyro package, attitude gyro and accelerometer package, hand controllers, flight director attitude indicator and some electronic components.

The Lunar Excursion Module Stabilization and Control System is part of the Grumman Aircraft Engineering Corporation development responsibility.

Reaction Control System

Grumman Aircraft Engineering Corporation began contract negotiations with the Marquardt Corporation in March 1963, for selected RCS components. The contract award is expected to be announced by mid-April 1963.

Preliminary design and installation studies have constituted the primary effort on the Lunar Excursion Module Reaction Control System during the reporting period. Relocation of the RCS engine clusters to positions at 45° to the "Y" and "Z" axes resulted in improved control dynamics and installation features.

Weight, reliability, and mission flexibility trade-off considerations necessary to accomodate the RCS design requirements, which will permit use of the RCS for the Δ V closing maneuver of up to 600 feet-per-second, are being evaluated by MSC. A prototype RCS engine has demonstrated a continuous firing duration of 1400 seconds, which is approximately three times that required for a Δ V closing maneuver.

The planning and preliminary design effort is underway for the Cold Flow Breadboard Test Rig to be used by Grumman Aircraft Engineering Corporation in evaluating system operating characteristics and pressurization system development. The Breadboard Test Rig will initially consist of off-the-shelf or simulated components. Breadboard testing is scheduled to begin by July 1, 1963.

Grumman Aircraft Engineering Corp., has reviewed the Command and Service Module RCS data with regard to potential common usage items. Components which show considerable promise for direct common usage application include the Service Module RCS engine, fill and drain valves, fill and vent valves, and solenoid valves. Other components are being evaluated from the standpoint of modifications necessary to fulfill Lunar Excursion Module.

Propulsion System

Grumman Aircraft Engineering Corp., began contract negotiations with Rocketdyne for development of the descent propulsion engine in February 1963. Negotiations are continuing and contract award is expected in early May 1963. Rocketdyne will develop the Lunar Excursion Module descent engine, using a helium injection technique to achieve a 10:1 thrust variation. A parallel development program will also be supported with another engine subcontractor using a method other than helium injection for thrust variation. Grumman Aircraft Engineering Corporation evaluation of Aerojet General, United Technology Corp., Space Technology Laboratories, and Thiokol for the parallel engine development program will begin on April 8, 1963. Contract award is expected in June 1963. One of the two descent engine contracts will be terminated after approximately one year.

Propulsion System considerations favor a four-tank configuration over six tanks in the descent stage, based on Grumman Aircraft Engineering Corporation studies which show lower residual propellants, fewer line connections, and less weight and complexity of lines for the four-tank configuration.

Grumman Aircraft Engineering Corporation began contract negotiations with Bell Aerosystems for development of the ascent propulsion engine in February 1963. Negotiations are continuing and contract award is expected in early May 1963. A study by Grumman Aircraft Engineering Corp., on an ablatively- versus regeneratively-cooled thrust chamber resulted in the choice of an ablatively-cooled thrust chamber for the 3500-pound-thrust ascent engine. The main factors in this decision were the flexibility of using either a radiation- or ablatively-cooled nozzle extension, and the low cooling margin available using regenerative cooling. Grumman Aircraft Engineering Corporation is considering the advantages of eliminating bladders from the ascent engines main propellant-tanks in favor of baffles for propellant slosh dampening and use of RCS engines for propellant ullage control. The major considerations are mission flexibility, system reliability and weight.

Communications System

The S-band radio frequencies and operational techniques for communications between the Ground Operational Support System (GOSS) and the Command and Service Modules and the GOSS and the Lunar Excursion Module have been resolved. Three S-band radio frequencies will be used:

Spacecraft Transmit/VCO Mode	2287.5 ms
Spacecraft Transmit/Auxiliary Oscillator Mode	2282.5 ms
Spacecraft Receive/Either Mode	2106.40625 ms

These frequencies will permit the use of electrically identical unified S-band equipment in both the Command Module and Lunar Excursion Module. Operationally, transmissions from the GOSS will be receivable by both modules at all times and the spacecraft-to-GOSS transmission frequency will be manually selected in both modules. The VCO mode will be used for coherent two-way doppler tracking. Authorization requests for the above frequencies, with detailed justification, are being prepared.

Requirements on the Lunar Excursion Module for communications with, and data processing of, information received from the spacecraft communications system have been defined and will be presented to Grumman Aircraft Engineering Corp., in April 1963.

A Project Apollo support plan and hardware requirement list have been prepared by MSC for both the Communications and Operational Instrumentation Systems. Further action on this plan is awaiting Grumman Aircraft Engineering Corporation vendor selection.

Operational Instrumentation System

Preliminary review of common usage studies indicate that all major instrumentation items will have common usage between the Command and Service Modules and Lunar Excursion Module.

Operational measurement requirements lists are being prepared by MSC and Grumman Aircraft Engineering Corp., for bench maintenance equipment, preflight automatic checkout equipment, inflight test system, displays, and telemetry.

Electrical Power System

Grumman Aircraft Engineering Corp., conducted a study of the Lunar Excursion Module Electrical Power System in order to select the optimum system configuration. The study included a preliminary analysis of electrical power requirements and a detail analysis of associated weight and reliability for general conceivable configurations of staged and unstaged power systems consisting of fuel cells, the cryocycle, and batteries. A study of the Electrical Power System was initiated on January 28, 1963, with a technical conference by Grumman Aircraft Engineering Corp., in which the following manufacturers participated: Allis-Chalmers, General Electric, Pratt and Whitney, Sunstrand, Tapco, Eagle-Picher, Electric Storage Battery, and Yardney.

The preliminary electrical-power load-analysis indicated that the total energy required for the Lunar Excursion Module mission, including the translunar phase, is 61.3 kilowatt hours. The maximum steady-state power required is 1725 watts, and the minimum steady-state power is 525 watts. This preliminary load analysis was used as a basis for the study of the electrical power system and also the selection of the system configuration.

As a result of the Grumman Aircraft Engineering Corp., study and a supporting study by MSC, an unstaged electrical power system configuration was selected which consists of three 50-percent fuel cells augmented by an auxiliary silver-zinc battery system to supply power for load spikes. The fuel cell and battery capacity is to be determined by the finalized electrical power load analysis.

Grumman Aircraft Engineering Corp., is continuing electrical power system studies in the following areas:

a. The electrical power load analysis is being updated to reflect the latest subsystem power requirements.

b. Trade-offs associated with sizing the auxiliary battery system to supply survival power in event of the loss of all three fuel cells.

c. The Lunar Excursion Module inverter requirements to determine the trade-offs involved between a centralized inverter system and individual system inverters.

d. Trade-offs involved with supplying Lunar Excursion Module translunar power from the Command and Service Modules as opposed to the module supplying its own translunar power.

e. Reactant tankage arrangement, reactant reserve philosophy, and trade-offs involved in integrating the Electrical Power System and Environmental Control System oxygen.

Studies of the Lunar Excursion Module lighting system, presently being conducted by Grumman Aircraft Engineering Corporation, indicate that a six-volt system is advantageous for integral instrument lighting and floodlighting because six-volt lamps can be qualified by environmental testing and can give the reliability required for the Lunar Excursion Module. Electroluminescent lighting is being investigated for possible use in panel lighting. Studies are also being conducted in connection with rendezvous lights, position lights, and exterior floodlighting. Grumman Aircraft Engineering Corp., is proceeding with procurement documentation for the Lunar Excursion Module fuel cells. MSC is presently reviewing the fuel cell specification and the Grumman Aircraft Engineering Corp., procurement plan.

Grumman Aircraft Engineering Corporation's common usage study indicates that the Command and Service Module inverter is the only item in the Electrical Power System that is a potential common usage item. MSC will continue to investigate the Project GEMINI fuel cell and Command and Service Module batteries and battery charger as potential common usage items.

MSC has determined the Environmental Control System requirements for inflight suit-leakage checks. This checkout will be accomplished after each suit donning, prior to a crewman assuming his duty station, to assure structural integrity of the suit assembly. A more comprehensive checkout procedure will be adopted for execution prior to extravehicular operations.

SPACE SUIT SYSTEM

Four interface meetings involving North American Aviation, Inc., Grumman Aircraft Engineering Corp., Hamilton Standard, and MSC have been conducted. The meetings were held in Downey, California, to afford easy availability of an up-to-date mock-up and spacecraft design details. Numerous problems involving suit mobility, suit storage, couch interface, and controls and displays interfaces have been defined and either solved or are under consideration.

The eye relief which will be provided by the suit visor has been established at 2.06 inches.

The Portable Life Support System battery charge capability will be furnished within the Command Module. This capability required only a manual voltage-cutoff be added to the existing charger at a weight cost of 0.5 pounds. The Portable Life Support System oxygen charging-capability will also be furnished within the Command Module. The only Command Module penalty associated with this capability is the existing valve and fitting required to effect the interface. Capability for recharge of the Portable Life Support System with water from Command Module stores was provided with no penalty to the spacecraft. Provision has also been made for storage of two of the Portable Life Support Systems in the Command Module.

A series of contractor conferences were held to determine the feasibility and advisability of liOH cartridge interchangeability between the Portable Life Support System, Command Module, and the Lunar Excursion Module. Specific recommendations by MSC are under preparation and will be available in early April 1963.

R AND D INSTRUMENTATION/COMMUNICATION SYSTEM

R&D instrumentation and communication equipment status for various Command and Service Module boilerplates is presented below.

a. All R&D equipment has been installed in BP-6 and is undergoing system tests in the North American Aviation, Inc., Project Apollo Test Operations area.

b. Most flight and spare equipment for BP-12 has been delivered to North American Aviation, Inc., and the necessary documentation has been transmitted.

c. The system breadboard test on BP-13 R&D equipment has been conducted. The major portion of flight equipment will be delivered to North American Aviation, Inc., early in April 1963. All the necessary documentation has been transmitted.

d. The BP-15 system breadboard tests are currently scheduled to begin May 1, 1963.

e. R&D equipment for BP-18 is on order. The transmittal of documentation to North American Aviation, Inc. has begun.

f. R&D equipment for BP-22 is being increased due to the recent addition of new flight measurement requirements.

g. The BP-23 system breadboard has begun. Preliminary tests are scheduled to begin in the early part of April 1963. The major portion of documentation supporting BP-23 has been transmitted to North American Aviation, Inc.

Measurement Requirements Lists for the Lunar Excursion Module R&D phase are being prepared by Grumman Aircraft Engineering Corp., and MSC and a tentative procurement schedule is being developed by MSC.

SCIENTIFIC INSTRUMENTATION

A detailed preliminary Project Apollo Scientific Instrumentation Implementation Plan has been prepared in coordination with NASA Headquarters, Jet Propulsion Laboratories, and Goddard Space Flight Center. It is expected that the first selection of scientific experiments for the initial Project Apollo flights will not be made until approximately December 1963, in order to allow the scientific community adequate time to properly prepare their experiment-proposals. Primary consideration will be given to those experiments which gain the most significant scientific information for the least weight and complexity and which are man-oriented and compatible with the spacecraft's restraints. Listed below, for interest information only, are some experiments/measurements which have been suggested.

a. Lunar Surface Bearing Strength

b. Seismic Experiment (Active and Passive)

c. Magnetic Field Measurements

d. Radiation Spectrum Measurements

e. Soil Density Measurements

f. Gravitation Field Measurements

It is expected that most experiments will be procured by MSC through the scientific community and through other NASA and Government organizations.

WEIGHT

The Project Apollo Spacecraft weights are shown below in Table IV. The weight apportionment for the individual modules comprising the Project Apollo Spacecraft have been modified. Control weights have been established based upon a 90,000-pound Saturn V payload capability. The design goal weights, which have been established, will yield a high degree of operational flexibility and mission reliability. The changes in the Control and Design Goal Weights have been coordinated and agreed upon by the Office of Manned Space Flight.

TABLE IV

	CONTROL WEIGHT	DESIGN GOAL WEIGHT	CURRENT WEIGHT	REMARKS
COMMAND MODULE (INCL CREW)	(9500)	(8500)	(8990)	
SERVICE MODULE	(50230)	(45615)	(46950)	ΔV MARGIN=10%
INERT (INCLUDE RESIDUAL PROPELLANTS)	10500	9500	9780	
USEABLE SPS PROPELLANT (ΔV=4801 FPS)	12200	10980	11450	I_{SP}=313.0 SEC
USEABLE SPS PROPELLANT (ΔV=3883 FPS)	27530	25135	25720	I_{SP}=313.0 SEC
TOTAL CM & SM	(59730)	(54115)	(55940)	
LUNAR EXCURSION MODULE (W/O CREW)	(26370)	(24500)	(24500)	ΔV MARGIN=10%
DESCENT STAGE (ΔV=7743 FPS)				I_{SP}=303.0 SEC
ASCENT STAGE (ΔV=6882 FPS)				I_{SP}=306.0 SEC
ADAPTER	(3400)	(3000)	(3110)	
EFFECTIVE WEIGHT	(500)	(500)	(500)	
TOTAL SPACECRAFT INJECTED WEIGHT	$\boxed{90000}$	$\boxed{82115}$	$\boxed{84050}$	
LAUNCH ESCAPE SYSTEM	6600	6400	6400	
TOTAL LAUNCH WEIGHT	96600	88515	90450	

Principal weight changes have resulted from:

a. Numerous minor design changes in the Command and Service Modules. A single significant decrease in weight was realized from a change in ablator material to AVCOAT 5026-39.

b. A decrease in inert weights of the Command and Service Modules.

c. A decrease in Isp to 313 seconds resulted in an increased Service Propulsion System propellant requirement (approximately 2500 pounds).

d. Grumman Aircraft Engineering Corp., proposal weight was an increase of 3000 pounds over the original MSC estimated weight allocation of 21,500.

e. Transfer of the Launch Escape System effective weight responsibility from MSFC to MSC.

FLIGHT TECHNOLOGY

Aerodynamics

Two strakes were added to the Command Module to eliminate the supersonic apex-forward trim point. These strakes are located in the yaw (x-y) plane and have a maximum span of one foot. Wind tunnel tests have been performed to define the static pitch plane aerodynamics of the Command Module and launch escape vehicle configuration over a Mach number range of 0.7 to 6.0. Angle of sideslip was limited to approximately 10° in these series of tests.

Static stability data for the Launch Escape Vehicle with rocket burning were successfully obtained over the Mach number range from 0.7 to 1.3 and angles of attack from -5° to 32°. These data were obtained on a hydrogen peroxide hot-jet model in the Langley 16-foot tunnel. The "jet-on" data are to be obtained in the supersonic region with a cold jet model at Arnold Engineering Development Center.

The 65-inch diameter flow separator disk, located at the base of the escape rocket was removed. The disk was originally employed to improve the static stability of the Launch Escape Vehicle. The disk required less weight than an equivalent amount of ballast. In the meantime, forward movement of the Launch Escape Vehicle center-of-gravity has been sufficient to permit removal of the disk without requiring additional ballast.

The design $\frac{L}{D}$ of 0.5 for the Command Module during reentry has been obtained through continued effort by North American Aviation, Inc., to increase lateral c.g. location.

As a result of a conference on Apollo spacecraft dynamic stability at Ames Research Center, it was concluded that the small-amplitude forced-oscillation wind tunnel test techniques previously used to determine dynamic damping derivatives of the Command Module and Launch Escape Vehicle are unsatisfactory. It was decided to use a free-oscillation large amplitude ($\alpha \approx 15°$) technique for future testing. Tests using this technique are planned during April 1963, (supersonic) and June 1963 (transonic).

A conference was held at MSC on results of wind tunnel and analytical investigations of Acoustics, Transient Aerodynamics, and Aeroelasticity on Saturn-Apollo vehicles. North American Aviation, Inc., Marshall Space Flight Center, Langley Research Center, Ames Research Center, NASA Headquarters, Lockheed and Douglas were represented at the conference. The conference resulted in three principal decisions.

a. Further correlation of results by research centers was recommended.

b. There are no requirements for loading pressure measurements, such as those used on the PSTL-1 Saturn I model) on the PSTL-2 model of the Saturn IB.

c. There are no aeroelastic problems indicated by present results for SA-6 through SA-111.

Aerodynamic Heat Transfer

Representative of North American Aviation, Inc., Langley Research Center, Ames Research Center and MSC met to compare and discuss estimates of Command Module reentry heating rates. There was agreement among those present on the blunt face heating estimates where a majority of the entry heating is experienced. Afterbody heating estimates were not as clearly defined. Work is proceeding at North American Aviation, Inc. to incorporate Project Mercury flight-test data and recent Project Apollo wind tunnel data into revised estimates of afterbody heating.

Ablative Material Thermal Performance

The current design of the ablative heat shield consists of 3/8-inch cell open-face, fiberglass-honeycomb filled with AVCOAT 5026-39 ablative material. The weight of the ablator and honeycomb is 1210.4

pounds plus 49.4 pounds of adhesive for a total of 1259.8 pounds.

The backup heat shield program initiated at North American Aviation, Inc., during the last quarter is continuing. The first phase of the program was a detailed comparison of the thermal performance of the AVCOAT 5026-39 ablative material with four other materials: Dow Corning DC-325, Emerson Electric T-500, General Electric ESM-1000 and a Langley Research Center modification of DC-325. The results of this initial phase were that all of the four alternative materials could equal or exceed the performance of the present 5026-39 material in terms of total heat shield weight. Therefore, the second phase of the backup program was initiated in which the thermo-structural characteristics of three materials will be investigated and compared. These three materials include the current-design heat shield ablative material, AVCOAT 5026-39, and the two most promising (T-500 and DC-325) of the four alternative materials investigated in the initial study phase. This second phase of the backup program will be completed and reported on during the next quarter.

Agreement was reached with the Langley Research Center to participate with them in the flight testing of Apollo Spacecraft materials. Langley Research Center will provide the SCOUT Launch vehicle, a portion of the instrumentation package and program technical direction. MSC will provide funds for the remainder of the instrumentation package and the instrumented nose caps made of the material to be tested. Authorization has been provided North American Aviation, Inc., to build the necessary nose caps. The flight test program is expected to begin early in October 1963.

This SCOUT test of Apollo Spacecraft ablative materials will provide early flight performance data and confirmation of ground testing methods at an entry velocity of about 30,000 feet per second.

Flight Dynamics

North American Aviation, Inc., and the MSC are jointly engaged in an analysis of the dynamic motions which the Command Module may encounter during a normal atmospheric entry or launch abort. The purpose of the investigation is to confirm that the present Command Module Reaction Control System is capable of damping spacecraft motions which could occur during flight.

The decision was made to use the Service Module RCS for accomplishing the initial Service Module S-IVB stage separation. The advantages of this technique over a posigrade rocket system are a weight advantage of 150 pounds, approximately $600,000 less development cost, and less complexity. The acceptability of the RCS separation technique depends upon the second-stage abort-detection rate being no greater than five degrees per second, that the Service Propulsion System start-up clearance is no greater than 40 inches, and that there is no safety criteria (such as launch vehicle explosion) which would require a more rapid separation.

Performance and Trajectories

An analysis was completed which defined the probability of unfavorable landing after pad abort. For all misalinements of the escape rocket and all winds within $\pm 3\sigma$ limits, there is a 10 percent probability of landing within 2000 feet of the launch vehicle. Since a 2000-foot circle around the launch vehicle would contain many acceptable landing sites, the probability of unfavorable landing is less than 10 percent. Further detailed definition of the unfavorable sites is being prepared before a final probability is established. Indications are that the present single pitch-control motor configuration of the Launch Escape System will be satisfactory.

Detailed trajectories for the Little Joe II/BP-12 high-dynamic-pressure flight test were reviewed to define nominal test initiation conditions. The conclusions were that the nominal test condition would be M = 0.9 at 20,000 feet (dynamic pressure = 600 psf) and that this would be obtained by terminating thrust on the Little Joe II several seconds prior to normal burnout.

Engineering Simulation Program

A revision to the planned simulation program included about a 25 percent reduction in the planned automatic computation time during the next $2\frac{1}{2}$ years. There was also a corresponding reduction in the planned manpower and equipment involved in the program.

The present program includes three "evaluators" and two "simulators". Only two visual displays are planned. Rework of the interior of evaluator E-1 was completed and a new display installed. Lighting and couch actuator installations have been completed in evaluator E-2 which should be operational during the next quarter.

Mission Natural Environment

Revised meteoroid environments for use in the Apollo Spacecraft design have been given to North American Aviation, Inc. The meteoroid environment represents a reduction in the severity of the Apollo Spacecraft Statement of Work environment. Ninety percent of the new total flux is considered to be of the "dustball" type with a density of 0.5 grams/cc while the remaining 10 percent is estimated to have a

[redacted]

density of 3.5 grams/cc. This reduction has been made possible by more recent analysis of the available data.

Attempts to perform the meteoroid simulation test program qualification firings at General Motors Corporation, Santa Barbara, California, have not yet proved successful. High-speed shaped-charge jet firings have been performed and seem to be satisfactory. However, due to difficulties with the radiographic equipment, no mass, velocity, or shape data have been obtained.

Efforts are continuing to obtain the backlog of data gathered by the Harvard Radio Meteor Project for reduction by MSC and future use in Apollo Spacecraft design.

The environment specification for solar radiation has also been revised. The new environment is described in terms of the probability of encountering a solar event of a given total number of protons with energy greater than 30 Mev during a 14-day period. This new specification was based on a statistical formulation of the Goddard Space Flight Center's solar proton-flux data, and represents a less stringent environment than the original Statement of Work. Grumman Aircraft Engineering Corp., has initiated a study to determine shielding weight requirements for this meteoroid flux.

RELIABILITY

Reliability and Test Plan Specifications were prepared for implementation by the Project Apollo contractors and their subcontractors. A workshop was held at MSC in February 1963, to review the reliability specification with Project Apollo contractors. A date will be set in the near future for invoking the Reliability and Test Plan Specifications on the Project Apollo contractors.

An effort has been applied toward standardization of reliability analysis and test data to eliminate duplication, and to enhance the capability for integration of the Command and Service Module, Lunar Excursion Module, and Guidance and Navigation System. This includes interface meetings between North American Aviation, Inc., Massachusetts Institute of Technology, and Grumman Aircraft Engineering Corporation to determine common parts usage, common subsystem module usage, common reliability analytical techniques, on-board spares standardization and optimization, and definition of standard mission criteria for reliability analyses.

[redacted]

Command and Service Module -

North American Aviation

North American Aviation, Inc., has conducted reliability analyses of the Project Apollo Command and Service Modules including logic diagrams for each of the subsystems, failure mode and effects analysis for each of the subsystems, mission simulation analysis to obtain onboard spares requirements and evaluate the effect of alternate modes of operation, data on results on the Project Apollo-Reliability Crew Safety Design Review Board, initiation of subcontractor reliability control, special studies on Lunar Excursion Module integration, data operations, reliability education, component technology, and qualification test program planning. Important results from the mission simulation analysis indicate that the predicted reliability of the spacecraft including the Lunar Excursion Module and the Saturn V launch vehicle is 0.69 on the basis of generic failure rates using state-of-the-art generic failure rates compared to the reliability objective of 0.965. The use of on-board spares increases the predicted reliability for the Command and Service Module to the required 0.965 reliability objective.

The Qualification Test Program was reoriented during the last quarter of 1962. The basic intent of the reoriented qualification program was to design a minimum test program consistent with criticality of the application and the reliability and crew safety objectives of the mission. A criticality ranking analysis was used to determine the degree of testing necessary for a given part, component, or subsystem. For example, the criticality ranking placed major emphasis on the Launch Escape System, Environmental Control System, Service Module Propulsion System, and Structures. Other systems had criticality rankings less than the above-mentioned subsystems.

Lunar Excursion Module -

Grumman Aircraft Engineering Corp.

Major efforts expended in the Lunar Excursion Module reliability have been:

a. The initial apportionment of reliability goals to each of the Lunar Excursion Module subsystems and 45 major equipments comprising these subsystems.

b. Conducting of specific reliability control engineering tasks, such as preparation and review of documentation associated with subcontracts.

Guidance and Navigation System

MIT Instrumentation Laboratory

The reliability objective for the Guidance and Navigation System is 0.989. A reliability analysis revealed that this objective can be met without the use of redundant or standby subsystems provided on-board spares are used. Apportionment of reliability to the various parts of the Guidance and Navigation subsystems has been completed.

Other reliability activities which are underway include initiation of a data center, failure mode and effects analysis, parts and materials improvement studies, and formulation of an integrated test program.

Little Joe II Launch Vehicle

General Dynamics/Convair

General Dynamics/Convair has completed initial reliability predictions on the Little Joe II launch vehicle. The results of this prediction indicate that the vehicle exceeds the reliability objective of 0.95. A failure mode and effects analysis has been completed on propulsion, measurement, and aerodynamic attitude and control. Various development and qualification tests have been initiated.

SPACECRAFT-LAUNCH VEHICLE INTEGRATION

Spacecraft-launch vehicle integration effects the integration of the spacecraft to the launch vehicle and its associated launch and flight control ground support equipment. This activity is accomplished through five MSC-Marshall Space Flight Center-Launch Operations Center coordination panels. Major accomplishments during this quarter include the following:

a. <u>Mechanical Integration Panel</u>

(1) It was agreed by MSC and Marshall Space Flight Center that the air conditioning barrier diaphragm will be part of the Apollo Spacecraft boilerplate design and will be on all boilerplates.

(2) The respective MSFC-MSC system of coordinates will be retained and referenced on all applicable interface documents.

(3) It was established that BP-9 would not be required as a spacecraft facilities test vehicle at the Launch Operations Center.

(4) An agreement was reached between MSC and MSFC that the Q-ball (differential-pressure device for measuring angle of attack, yaw, and dynamic pressure) is required on all R&D flights.

b. Flight Mechanics, Dynamics and Control Panel

(1) The MSC and MSFC have agreed that all performance values for the nominal missions for Saturn I, IB, and V launch vehicles do not include the engine out capability. (MSFC is investigating engine out capabilities on Saturn I, IB, and V from a control and structural viewpoint for use in abort studies and/or alternate missions.)

(2) The Launch Escape System will be jettisoned ten seconds after S-IV ignition on Saturn I vehicles. (MSC preliminary estimate for Saturn IB and V is that the Launch Escape System will be jettisoned twenty seconds after S-IVB ignition.)

(3) MSC has no requirements for retro rockets on the S-IV or S-IVB stages due to spacecraft separation and operational requirements.

(4) Free flight, rather than mechanical or tethered, is still considered by MSC to be the primary mode for docking.

(5) MSC and MSFC recommended that both Centers should continue efforts to define LOX-LH_2 explosion characteristics.

c. Instrumentation and Communication Panel

(1) An agreement was obtained between MSC and MSFC on the location of the sensors for the bending mode measurements on the spacecraft.

(2) The Instrumentation and Communication Panel's charter was revised and agreed to by both Centers to include interface areas between the launch vehicle and the GOSS network. A sub-panel was established to assure compatibility between the digital command systems being used by MSC and MSFC. A second sub-panel has been established to review the frequencies to be used on the spacecraft and the launch vehicle to eliminate any interference between the frequencies which will be used.

d. Electrical Systems Panel

(1) MSC and MSFC have agreed on a document that defines the Saturn I vehicle electrical interface.

(2) It has been established that in the event of a cancellation occurring after SA-6 spacecraft umbilical disconnect, the spacecraft systems will be restored to desired conditions by signals routed to the spacecraft through the launch vehicle.

(3) MSFC's ground support equipment for Complexes 34 and 37 will transmit a signal to MSC's GSE to indicate when the umbilical drop command has been initiated.

(4) S-I/S-IV separation signals will be furnished in a redundant manner to MSC's GSE through the Automatic Ground Control Station at Complexes 34 and 37.

(5) Electrical functions routed from the spacecraft to MSC's GSE via the launch vehicle will be routed via the Automatic Ground Control Station in cases where MSFC's GSE will be routed to MSC's GSE via the Launch Operations Center.

An initial failure effects analysis of the Saturn I was completed in January by MSFC. From the results of this failure effects analysis, MSFC proposed that certain parameters be monitored for a launch vehicle emergency detection system. After careful evaluation of the proposal, considering warning times available, reaction times, characteristics of the failure modes, and several discussions with MSFC regarding specific failure modes, MSC presented their recommendations regarding the Saturn I emergency detection system to MSFC. A joint MSC-MSFC meeting was held in March 1963 to discuss the proposals. Agreement was reached between the two Centers on an emergency detection system which will be a combination of an automatic and manual abort system. Most noteworthy agreement was to take design action in the S-IV stage to detect incipient catastrophic failures of the engines and, as a function of stage logic, shut down the engines prior to the catastrophic event. This philosophy will be carried over to the Saturn IB and Saturn V Launch vehicles. MSFC plans to have a preliminary Saturn I emergency detection system design ready for review in April 1963.

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MANUFACTURING

MOCK-UPS

All mock-ups have been completed. Final inspection and review of the complete spacecraft (configuration control) mock-up (M-18) will be deferred until all configuration changes are completed and the design is frozen.

BOILERPLATES

To date, manufacturing of Boilerplates 1, 2, 3, 6, 9, 12, 13, 19, and 25 has been completed.

Boilerplates 1, 2, 3, and 19 have been used for land and impact tests and parachute drop tests. Results are reported under the Command and Service Modules Earth Landing System section. Boilerplate 9 has been used at MSC, Houston, for structural measurement (reported in Service Module Structural System section) and is to be shipped to MSFC in early April 1963. Boilerplate 6 is undergoing test and operations checkout at North American Aviation, Inc., and Boilerplates 12 and 13 are in final assembly. Detailed status of these boilerplates is presented below:

a. Boilerplate 6.- Command Module Boilerplate 6 will be used on the first pad abort test to determine the stability characteristics of the launch escape configuration and the operational characteristics of the escape system for an abort from the pad.

The boilerplate left the manufacturing area on March 8, 1963, and is now in the Project Apollo Test and Operations area at North American Aviation, Inc., Downey, California, where final integrated systems checks will be performed prior to shipment of the boilerplate to White Sands Missile Range. Major configuration changes that have occurred on BP-6 are the addition of strakes on the Command Module, change of the tower release system to an explosive-bolt tower separation system, the deletion of the flow separator on the launch escape system and redesign of the apex heat shield release system to eliminate the cable cutter, change of the time delay for the release of the apex heat shield from 1.5 to 3.5 seconds, and the makeup and installation of a new wiring harness because of faulty connectors. All outstanding systems are currently being installed, and attendant GSE is in Project Apollo Test and Operations Area.

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The present schedule for shipment of the boilerplate and equipment to White Sands Missile Range is April 26, 1963. This is a delay of 11 days due to parts shortage and late deliveries by vendors to North American Aviation, Inc. It is anticipated that not all of this slippage will be reflected in the launch date of BP-6.

The White Sands Missile Range facilities required in support of this test are on schedule, and no delay in facilities can be foreseen.

b. Boilerplate 12.- Command Module Boilerplate 12 will be used on the second Little Joe II flight test to demonstrate the operation of the Launch Escape System at high dynamic pressure in the transonic speed range. Abort will be initiated at 20,000 feet and Mach Number 0.9, simulating a point on a nominal C-1 trajectory.

Boilerplate 12 has completed the first phase of manufacturing and is now in final assembly where wiring harnesses, pressure tubing and system's installation is being accomplished. Final assembly is expected to be complete about June 1, 1963, and the factory checkout will follow immediately thereafter. The date for these events is 6 to 8 weeks behind schedule and the current detailed plans for checkout and operations indicate that about 50 percent of this delay can be recovered. Significant changes to BP-12 that have been made are those effected on BP-6, plus the addition of the new design Command Module-Service Module separation system and the installation of two onboard cameras. These cameras will monitor the Command Module-Little Joe II separation plus separation of the launch escape tower and deployment of the parachute recovery system.

Present status of the Little Joe II launch vehicle for this flight test indicate that manufacturing will be completed well in advance of the date required for support of the launch date.

Launch complex facilities at White Sands Missile Range will have previously been used for the first pad abort test and the Little Joe II qualification test and no refurbishment problems are anticipated in preparation of this test.

c. Boilerplate 13.- The spacecraft Boilerplate 13 will be used to measure launch environment on the Saturn I, SA-6, and will be ballasted according to the current Saturn I orbital capability of 18,600 pounds.

Structural assembly has been completed on the Service Module, insert, and adapter. The Command Module structural assembly, including the installation of cork insulation, was completed on March 29, 1963. Fabrication of the launch escape tower was not started in this quarter, as planned, because of a shortage of titanium tubing. The R&D instrumentation breadboard has been completed and the wiring checked out.

Instrumentation installation on the breadboard is nearly completed, with the exception of a few critical transducers, signal conditioning amplifiers, and amplifier racks. One group of pressure-transducers has been shipped to the contractor. Major configuration changes that have been incorporated in the design of BP-13 are the addition of strakes to the Command Module, the flow separator on the escape tower was deleted, the tower-jettison motor-initiator was changed from an explosive bridge wire (EBW) to a hot-wire system, the tower separation system was changed to an explosive bolt system, and structural stiffeners were added to the apex heat shield. The electrical power system batteries were changed from 60 amp-hour to 120 amp-hour units, the requirement of turning off two telemetry systems and reducing to low power the third telemetry system after orbital injection was deleted, and fifteen fluctuating pressure measurements were relocated in the spacecraft.

All known GSE requirements for BP-13 checkout and support at Downey, California and the Cape have been defined. The need dates for the GSE have been determined. The equipment is in the design or the procurement and/or manufacturing phase. Spacecraft-Launch Vehicle electrical and mechanical interfaces have been defined and several interface lists have been generated for study.

The spacecraft is on schedule and it is planned to meet the October 1, 1963, delivery to AMR, for December 15, 1963, launch.

Manufacturing has begun on Boilerplates 15, 22, and 23. BP-15 and BP-23 are backups for BP-13 and BP-12, respectively. Boilerplate 22 will be used on the fifth Little Joe flight to determine Command Module stability at high altitude abort.

Design is underway on Boilerplates 16, 18, and 26. Boilerplate 16 will be used for SA-9 micrometeoroid experiment. Boilerplate 26 will be used for an micrometeoroid experiment and Boilerplate 18 will be used as an alternate payload for spacecraft structural qualification on SA-8.

AIRFRAMES

Design and/or manufacturing are underway for Airframes 001, 004, 006, 009, 008, 010, and 011. All airframe Service Module design is on schedule with some manufacturing to begin during the next quarter. Design and manufacturing of the airframe Command Modules is underway. Status of the individual airframes is presented below:

a. Airframe 009 (Spacecraft Qualification SA-10).- Complete design release of the Command Module structure drawings was accomplished in

January 1963, and manufacturing is underway. Service Module design is on schedule and structure design release is scheduled for April 1963.

b. Airframe 001 (Service Propulsion and Combined Systems Tests).- Command Module structural design release was made in January 1963, and manufacture has been underway since October 1962. Service Module design is underway and structural design release is scheduled for April 1963.

c. Airframe 004 (Structural Test).- Design release of the Command Module structure was accomplished in January 1963. Design of the Service Module is on schedule. Complete design release has been made on the Service Module structure and subsystem installation.

d. Airframe 006 (Vibration and Acoustic Tests).- Design release of the Command Module structure was accomplished in January 1963, and manufacturing has begun. Service Module design is on schedule, with manufacturing scheduled to begin in May 1963.

e. Airframe 008 (Environmental Proof).- Command Module structural design release occurred in early January 1963, and manufacturing began. Service Module design is on schedule, and structure design release is scheduled for April 1963, with manufacturing scheduled to begin in June June 1963.

g. Airframe 011 (First Manned Flight - SA-111).- Command Module structural design release was accomplished in late December 1962. Design of the Service Module structure is on schedule, with structure design release scheduled for April 1963.

QUALITY ASSURANCE

An "Apollo Quality Assurance Program Manual" defining Project Apollo requirements in complying with NPC 200-2 is in preparation and will be distributed to contractors in April 1963. Implementation documents on NPC 200-1 and NPC 200-3 are also under preparation.

Quality Control Program Plans were received from North American Aviation, Inc., Grumman Aircraft Engineering Corporation, and Massachusetts Institute of Technology and have been reviewed by MSC.

A meeting was held at MSC in February 1963, between MSC and Government Inspection Agency representatives at Massachusetts Institute of Technology associate contractor facilities. Relationships between MSC, and Massachusetts Institute of Technology's associate contractors, the applicability of NPC 200-1 and NPC 200-2, and specific Government

Inspection Agency problem areas such as reporting lines, inspection criteria, et cetera, were resolved.

Authorizations have been given to the NASA Western Operations Office and to various Department of Defense inspection agencies to perform quality functions at Project Apollo contractors' plants (North American Aviation, Inc., Grumman Aircraft Engineering Corporation, and Massachusetts Institute of Technology associate contractors, General Dynamics/Convair, and Aerojet-General Corp.). Delegation of the quality assurance functions has not been made at Massachusetts Institute of Technology. At North American Aviation, Inc., and Grumman Aircraft Engineering Corporation, the delegation is restricted to primarily hardware inspection. Quality engineering efforts are to be accomplished by MSC.

Inspection stamps have been ordered for Government inspection agencies in accordance with NASA's directive that the quality status of all NASA-procured space system hardware be identified by inspection stamps.

CREW TRAINING

Negotiations on the training equipment contract with North American Aviation, Inc. (G.O. 7125) was completed in January 1963. Negotiation was on the basis of one part-task trainer, subcontract of the Mission Simulator, and training plan support. MSC reviewed a draft specification of the one part-task trainer and gave comments to North American Aviation, Inc. A final draft of the specification will be submitted on April 15, 1963. The Project Apollo Mission Simulator proposals have been evaluated by North American Aviation, Inc., and Link Division of General Precision, Inc., is recommended as the source contractor. MSC has concurred in the recommendation. MSC and North American Aviation, Inc., personnel have reviewed the procurement specifications and performance criteria in preparation for subcontract negotiation.

Flight Crew personnel are being familiarized with details of the Apollo Spacecraft system through participation in technical discussions and review of the crew controls and displays. Assignments among the flight crew personnel to areas of particular specialization are shown in Table V.

TABLE V.- FLIGHT CREW ASSIGNMENTS

Area	Personnel
Project Apollo-General	J. Glenn
LEM-General	M. S. Carpenter
Operations and Training	W. M. Schirra
Training	N. A. Armstrong
Boosters	F. Borman
Communications, Instrumentation, and Range Integration	T. P. Stafford
Recovery Operations	J. A. Lovell
Flight Control Systems	E. A. White
Cockpit Layout and Systems Integration	C. Conrad
Crew Equipment	J. W. Young
Guidance and Navigation	J. McDivitt
Electrical and Sequential Systems and Mission Planning	E. See

SIMULATORS

ENGINEERING SIMULATION PROGRAM

Efforts have been made to familiarize Grumman Aircraft Engineering Corporation personnel with simulator facilities at various NASA and industrial installations which might be used to implement the Lunar Excursion Module Program. At MSC, various organizations have presented resumés of their simulation programs and facilities. These involve the MSC analogue simulation facility, North American Aviation, Inc.-Columbus six-degree-of-freedom simulator, and Chance-Vought and Martin Company simulation facilities. Grumman Aircraft Engineering Corporation and MSC personnel visited Langley Research Center for a briefing which included their rendezvous docking simulator, lunar landing research facility, lunar orbit and landing approach simulator, and other simulator facilities.

Grumman Aircraft Engineering Corporation has presented to MSC their proposed simulation program. In this program, Phase A simulations are somewhat crude in that cockpits and visual displays are crude when compared to the ultimate objectives. These simulations are oriented toward providing engineering information which would affect Lunar Excursion Module design decisions. Phase B simulations are quite sophisticated and simulate Lunar Excursion Module hardware and visual displays as realistically as is feasible. This phase is oriented toward detailed systems analysis. Phase A of the separation and docking simulation as well as the hover and landing simulation is presently in progress. The separation and docking simulation is being run at North American Aviation, Inc.-Columbus, while the hover and landing simulation is being run at the Grumman Aircraft Engineering Corporation facility at Bethpage, N. Y.

FREE-FLYING LUNAR EXCURSION MODULE LANDING SIMULATOR-TRAINER

In response to the contractual requirement to conduct conceptual designs of free-flight vehicles for terminal approach, hover, and landing test, Grumman Aircraft Engineering Corporation has issued a preliminary report, "LTA-9 Feasibility Study Report." This report indicates that it is feasible to design a landing simulator/trainer capable of duplicating the flying characteristics of the Lunar Excursion Module in the lunar environment. To accomplish this, six turbojet engines are employed to support five-sixths of the instantaneous vehicle weight, and their thrust vector is maintained vertical and is independent of the vehicle attitude. The remaining thrust is supplied by a modified Lunar Excursion Module descent engine and is controlled by the crewman as in the lunar environment.

Grumman Aircraft Engineering Corporation is continuing their effort in this area and is investigating the feasibility of employing an all-jet descent stage in addition to the use of a minimum-modified Lunar Excursion Module for atmospheric flight test.

Preliminary reviews of Grumman Aircraft Engineering Corporation activities in this area have led the MSC to direct them to apply the major portion of their remaining efforts to studying the feasibility of a minimum-modified Lunar Excursion Module. The intent is to emphasize the gaining of systems experience and retaining a minimal flight performance. This particular approach would not involve a turbojet levitation system. Grumman Aircraft Engineering Corporation will present a technical summary to MSC by April 15, 1963, with a final report to be published by May 1, 1963.

OPERATIONS

SPACECRAFT CHECKOUT

A Project Apollo system checkout requirements specification, establishing the applicable phases of testing to be chronologically performed on the spacecraft systems from the contractor assembly area through launch, has been published.

Further definition of Preflight Automatic Checkout Equipment (PACE) operational function, hardware interfaces, and test point requirements has been accomplished. A Project Apollo measurement list has been published which lists and defines airframe test points.

Current MSC approved ground support equipment suggested by North American Aviation, Inc., totals over 200 models and 800 units. A design review was conducted for the purpose of determining North American Aviation, Inc., GSE design adequacy.

Grumman Aircraft Engineering Corporation's Lunar Excursion Module checkout philosophy, equipment, and procedures have been reviewed, with no significant problems apparent.

PREFLIGHT

Development of the PACE ground station is on schedule. As currently scheduled, the first use of a PACE ground station will be in support of the North American Aviation, Inc., systems test of an airframe on January 1, 1964. Schedules for design, manufacture, and required usage dates for all GSE items to support launch vehicles up through manned orbital flight have been compiled.

FLIGHT

A concept for the In-Flight Test System has been established, and the design is proceeding for implementation. The In-Flight Test System will isolate faults to the lowest replaceable module. The concept changes have been incorporated into the In-Flight Test System procurement specification, and procurement action will proceed based on this revised specification.

MSC has submitted to the Office of Manned Space Flight the Program Instrumentation Requirements Document (PIRD) for the Saturn I program. It is anticipated that in the future the MSC and MSFC will jointly prepare a Requirements Document for review by the Office of Manned Space Flight which will represent both the spacecraft and launch vehicle requirements for ground support.

A contract has been signed with Philco Western Development Laboratory for the design, implementation, operation, and maintenance of the Integrated Mission Control Center (IMCC) at Houston, Texas. The contractor, under direction of MSC, will also be responsible for integration of the IMCC, its support equipment, and the total Ground Operational Support Systems. Construction of the IMCC building is continuing. Wiring and equipment installation will begin in September, and initial occupancy is planned for October 1963. Checkout will begin in November 1963.

MSC is reviewing the basic criteria involved in recovery of the crew and Project Apollo spacecraft. The need for Recovery Control Centers (RCC) and tradeoff studies in selecting water or land as the primary recovery area is the major consideration. The IMCC contractor may be directed to proceed with RCC design studies subsequent to the determination of the basic criteria.

GROUND TEST PROGRAM

SERVICE MODULE PROPULSION SYSTEM GROUND TESTS

Test Fixture F-2 is being developed to obtain data from which an evaluation of the Service Module Propulsion System can be accomplished under normal and off-limits conditions. The Test Fixture F-2 for White Sands Missile Range is approximately one month ahead of schedule. It currently is to be instrumented at North American Aviation, Inc., and shipped to White Sands Missile Range in August 1963. The first hot firing is scheduled for November 1, 1963. Prior to the first firing, North American Aviation, Inc., will check out the fixture at White Sands Missile Range and conduct cold flow tests. After the initial firings, the off-the-shelf components are to be replaced using flight-weight components as they become available. The North American Aviation, Inc., Test Plan for operation of F-2 is well under way.

Planning was initiated in December 1962, to incorporate provisions for manning AFRM 001 mated tests at White Sands Missile Range during propulsion system operation. AFRM 001 is an actual Command Module and Service Module equipped with the necessary flight configured systems. Plans for the manned-mated tests have continued through this reporting period and should be completed during the second quarter of this year. Details for the test stand, airframe, and supporting equipment are currently being finalized. Considerable attention has been given to MSC and North American Aviation, Inc's., safety considerations required for the manned-mated tests.

Contract NAS 9-627, awarded to North American Aviation, Inc., for development of the Propulsion System Development Facility was partially terminated on March 25, 1963. In order to expedite the necessary A&E design work required to complete this facility, a committee was established which consists of representatives from MSC, North American Aviation, Inc., and the Corps of Engineers. The overall impact as to the completion of the test site and test program for Test Fixture F-2 and AFRM 001 is unknown at this time.

ENVIRONMENTAL GROUND TESTS

AFRM 008 will be used to evaluate the complete Project Apollo spacecraft configuration, except the launch escape tower, under simulated mission thermal-vacuum conditions. The spacecraft will be tested in sequence providing progressive levels of qualification required to support the various Project Apollo flight missions.

North American Aviation, Inc., will ship AFRM 008 directly to MSC in late 1964. All thermal-vacuum tests on AFRM 008 will be conducted in the MSC Space Environmental Facility. This facility will be ready for vacuum testing in September 1964, to support the initial Project Apollo flights. Spacecraft testing is scheduled to start in October 1964.

North American Aviation, Inc., plans to ship the GSE for AFRM 008 to MSC beginning June 1, 1964. The supporting GSE is to be checked out prior to receipt of the airframe.

FLIGHT PROGRAM

PAD ABORT AND LITTLE JOE II

Changes have been made in the Pad Abort and Little Joe II launch schedule (fig. 4) which include the addition of a Little Joe II control system qualification flight, rescheduling of the Pad Abort 2 (AFRM 010) to September 15, 1964, and Mission A-003 (High "q" Abort AFRM 002) to November 1, 1964.

The Little Joe II control system qualification flight will be made prior to the high-altitude abort flight and is scheduled for April 1, 1964, at White Sands Missile Range. The dummy payload will no not be separated from the launch vehicle.

SATURN

The Project Apollo Mission Schedule is shown in figures 4-7. Mission objective and configuration data for Project Apollo flights, using the Saturn I launch vehicle, has been tentatively determined. The Saturn I flight program consists of two boilerplate spacecraft for launch environment, one boilerplate spacecraft for structural qualification, and one airframe for unmanned spacecraft qualification prior to the first manned flight. Two boilerplates will be made available to MSFC for micrometeoroid experiments. Development flights subsequent to the first manned flight using Saturn I, IB, and V launch vehicles are reflected on the schedule. Spacecraft configuration and detail mission objectives for Saturn IB and V have not yet been defined.

Launch Environment

The first launch exit environment test will be made with Boilerplate 13. The spacecraft will be launched on SA-6 from Complex 37B at a launch azimuth of 90° and the roll program will provide a flight azimuth of 105°. The escape tower will be jettisoned 10 seconds after S-IV ignition. The S-IV, the adapter, and the Command and Service Modules will be placed in a 100 nautical mile orbit. No recovery is planned. Objectives of this flight are as follows:

a. Qualify the launch vehicle

b. Demonstrate the physical compatibility of launch vehicle and spacecraft under flight and preflight conditions.

c. Determine the launch and exit environmental parameters to verify design criteria

d. Demonstrate satisfactory separation of launch escape tower

e. Demonstrate compatibility of the R&D communications and instrumentation systems with the launch vehicle systems

f. Determine operational suitability of AMR ground tracking systems

Boilerplate 15 will be configured for the launch exit environment mission on SA-7 to obtain a second data point. Flight plan and mission objectives are as defined for BP-13.

Micrometeoroid Experiments

Boilerplate hardware is being provided by MSC at the request of MSFC for micrometeoroid experiments on SA-9 and SA-8.

Mission requirements and flight plans will be determined by MSFC. Project Apollo secondary objectives for these flights will be emergency detection system checkout and normal tower jettison.

Structural Qualification

Boilerplate 18 is proposed as an alternate payload for SA-8 to qualify the adapter and Service Module structures and the Spacecraft-Launch Vehicle separation system. This mission is presently programed as a replacement for the second micrometeoroid experiment assuming the success of the first micrometeoroid experiment on SA-9. The Spacecraft will be launched from Complex 37B at a launch azimuth of 90° and the roll program will provide a flight azimuth of 72°. The escape tower will be jettisoned 10 seconds after S-IV ignition. The Spacecraft will separate from the S-IV at burnout. Spacecraft orbit will be 100 nautical miles. No recovery is planned. Flight objectives are as follows:

a. Qualify the launch vehicle

b. Demonstrate the structural integrity of the production adapter and Service Module structures for flight loads to be encountered on manned Saturn I flight

c. Evaluate the separation of the Command and Service Modules from the adapter

d. Evaluate the operation of the complete crew safety system.

Spacecraft Qualification

AFRM 009 will be launched on SA-10 to qualify the Command and Service Module systems prior to the first manned flight. The mission profile has not been defined, however, both orbital and suborbital flights are being studied. This mission will be discussed in detail in the next Quarterly Status Report.

LITTLE JOE II LAUNCH VEHICLE DEVELOPMENT

Manufacture of the first Little Joe II Launch Vehicle and launcher have been completed by General Dynamics/Convair. The Launch Vehicle has been assembled on the launcher in operational configuration and the launcher has been functionally tested at General Dynamics/Convair. Algol and Recruit rocket motor mock-ups were installed with associated GSE for mate checks and operational handling. A qualification flight will be made in July 1963, as scheduled. The second vehicle for the first spacecraft flight (BP-12) is nearly complete in the final assembly fixture. A spare launcher is to be completed in June 1963. A sketch of the vehicle on launcher with payload is shown in figure 8.

Aerojet-General has completed the first two rocket motors for canted-nozzle qualification tests. The first nozzle has been completed and the first of three rocket motor static firings for qualification of the nozzle is to be conducted on April 4, 1963.

A qualification flight of the Launch Vehicle with a control system will be made prior to the high altitude abort flight (BP-22). The qualification flight is tentatively scheduled for April 1, 1964, at White Sands Missile Range. The dummy payload will not be recovered. Purchase requests have been processed for two Launch Vehicles with control systems and sixteen rocket motors with canted nozzles to support these tests.

FACILITIES

The status of industrial facilities at Downey, California, vary from construction completed to design in progress.

a. The Impact Test Facility construction has been completed, and some instrumented boilerplate drops have been accomplished.

b. The Assembly and Manufacturing Building 1 modification is completed, except for painting, and is in operation.

c. The plaster master and bonding and test facilities construction was started in December 1962. The plaster master facility construction has been completed and the facility is in operation, and the bonding and test facility construction is scheduled to be completed in April 1963.

d. Construction of the Radiographic Facility was started in January 1963, and is scheduled to be completed in April 1963.

e. The design of the Systems Integration and Checkout Facility has been completed.

Design is in progress for all other facilities scheduled for Downey, California. These are Data Ground Station, Building 6 modifications, and Space Systems Development Facility. The addition to the hangar at Hanscom Air Force Base for Massachusetts Institute of Technology's use is nearly completed. Occupancy is scheduled for April 1963. This facility will be used to support development of the Navigation and Guidance System.

The contract for construction of Propulsion Development Facilities at White Sands Missile Range by North American Aviation, Inc., has been partially terminated, and redistribution of work between them and the Corps of Engineers is in progress. The necessary schedule revisions will be determined as soon as possible. Construction of the suborbital launch complex at White Sands Missile Range is on schedule for support of Little Joe II and the pad abort operations. The modifications to the weight and balance building have been completed. Headquarters approved the inclusion of a Vertical Assembly Building on March 12, 1963.

Authority has been given to North American Aviation, Inc., to authorize subcontractors to procure required facilities. The subcontractors were Beech Aircraft Company, Collins Radio, and AVCO. Formal facilities contracts are being prepared for these contractors and Pratt and Whitney. The Minneapolis-Honeywell Regulator Company facilities contract has been transmitted to NASA Headquarters for approval.

Modifications to the C-133A airplane required to support the Apollo spacecraft earth landing system development and qualification tests have been completed. The C-133A has been qualified for dropping boilerplate test articles by successfully dropping a dummy test article.

MSC facilities which have a definite schedule to support Project Apollo are the Mission Control Center and one of the altitude chambers. The Mission Control Center is currently on schedule to support the

GEMINI Project. The GEMINI Project requirement precedes the Project Apollo requirement for Earth Orbital mission control requirements. The altitude chamber will be able to support the Apollo Spacecraft in September 1964, by providing vacuum environmental requirements.

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

Grumman Aircraft Engineering Corporation is developing approximately 50 networks for the Lunar Excursion Module. These networks will be submitted to MSC within six months after contract go-ahead. There are 22 major items of functional responsibility to be covered by networks. Four networks in the propulsion area have been prepared and submitted to MSC for evaluation. The second set of propulsion networks will be received by MSC within the next week, as well as the first submittal of networks in the areas of navigation and guidance and stability and control.

Program Management Plan (PMP) milestones are being developed concurrently with PERT networks and will be incorporated into the networks as rapidly as possible. It is anticipated that PMP milestones will be eliminated within six months and PERT will be functioning satisfactorily.

The North American Aviation, Inc., PERT system is being exercised to perfect the reporting procedures. Trial run reporting is being conducted every two weeks on 23 of the 26 GO areas.

REFERENCES

1. Project Apollo Lunar Landing Mission Design Plan, MSC, Apollo Spacecraft Project Office, Systems Integration. April 1963. Confidential.

[redacted]

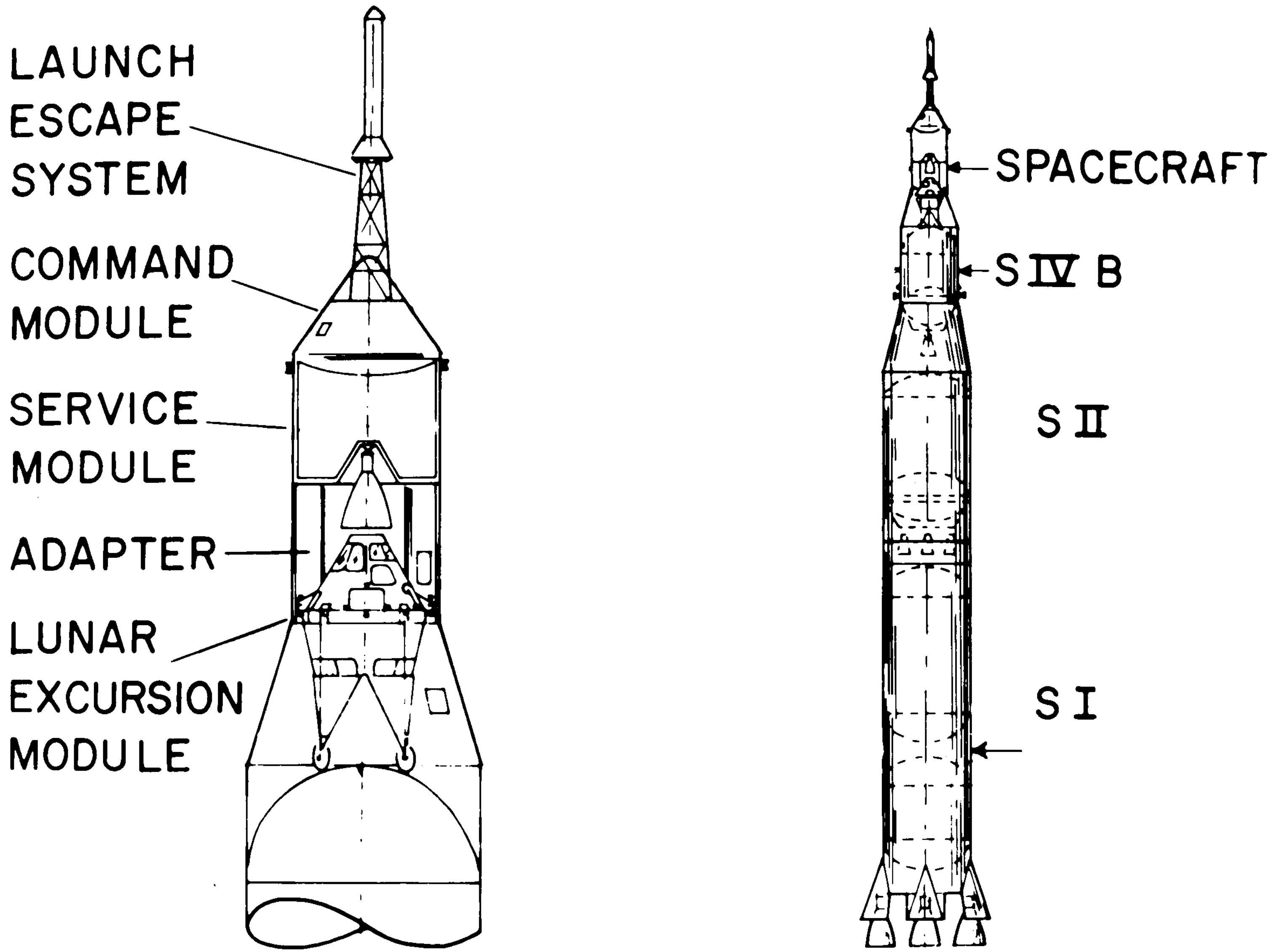

Figure 1. Apollo Space Vehicle Configuration

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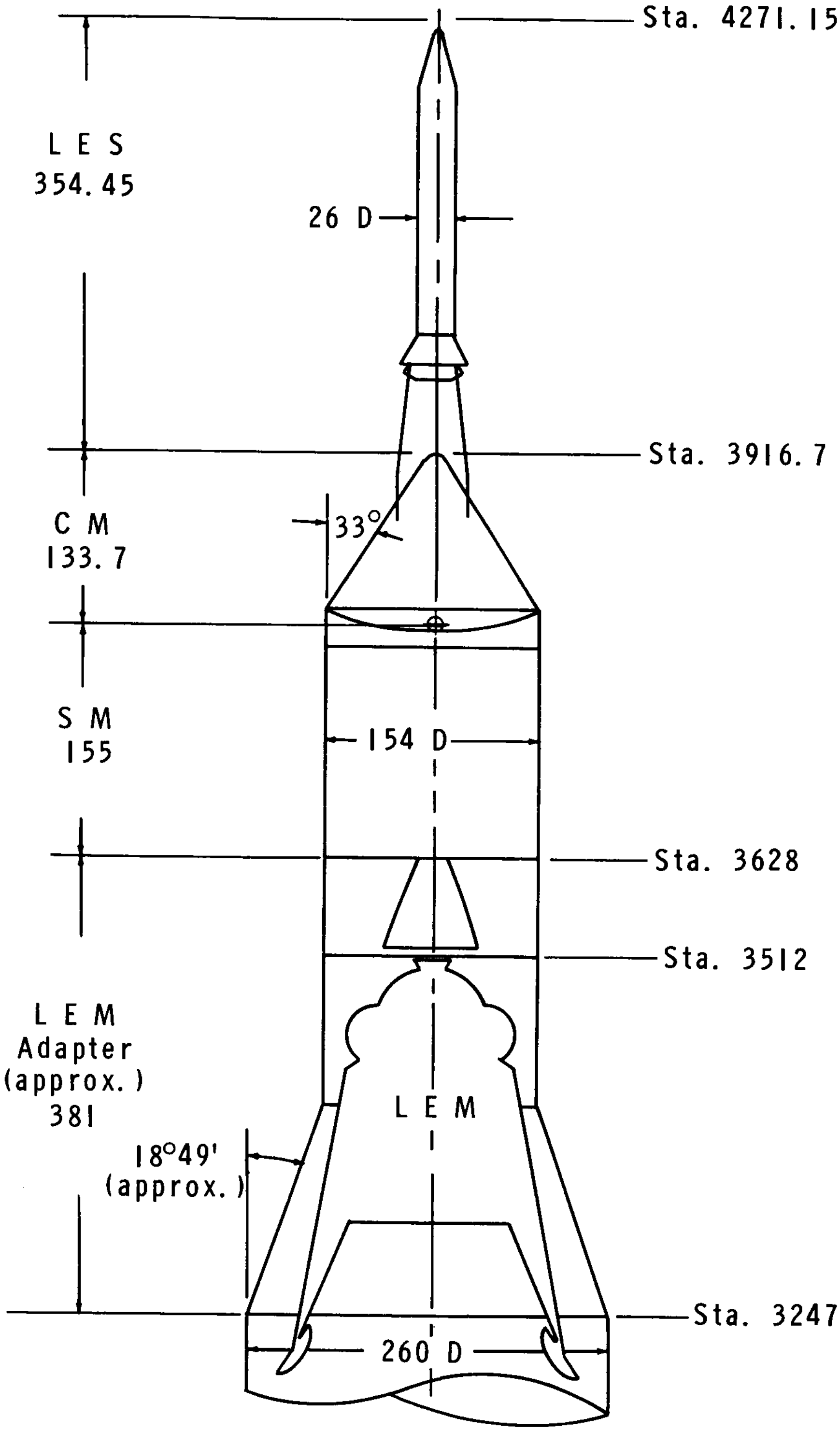

Figure 2. Apollo Spacecraft Configuration

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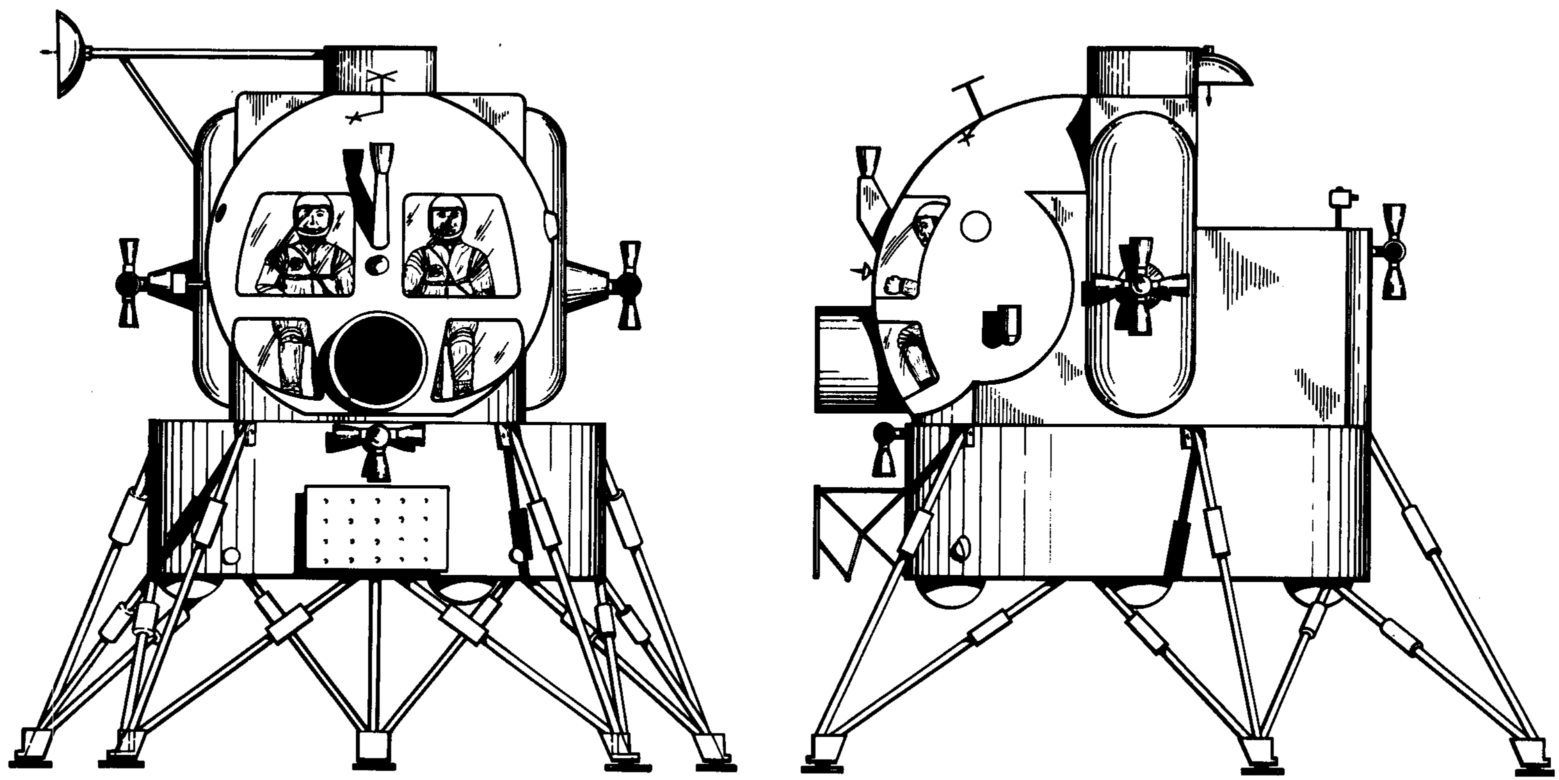

Figure 3. GAEC Proposal LEM Configuration

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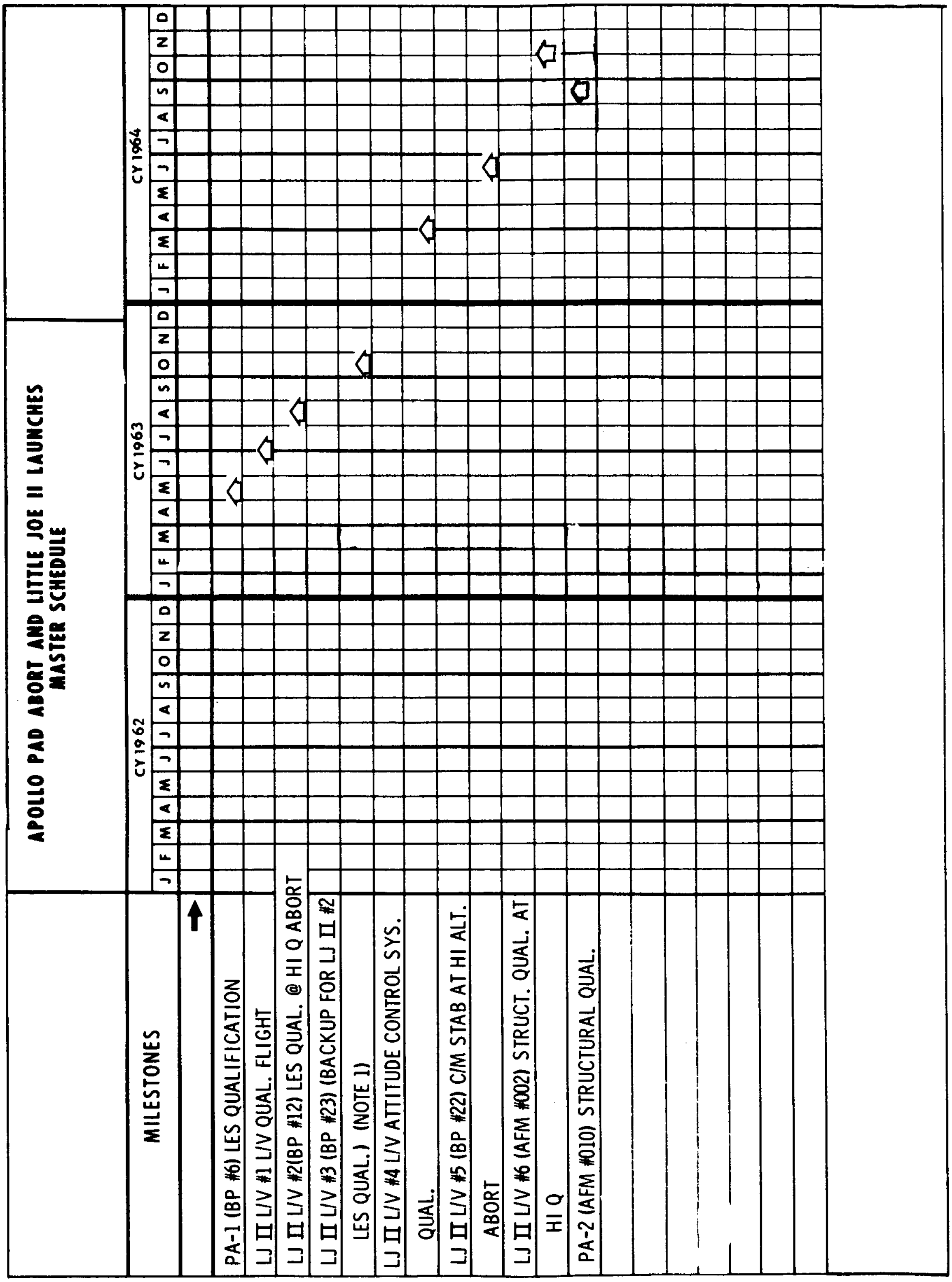

Figure 4 - Apollo Pad Abort and Little Joe II Launches

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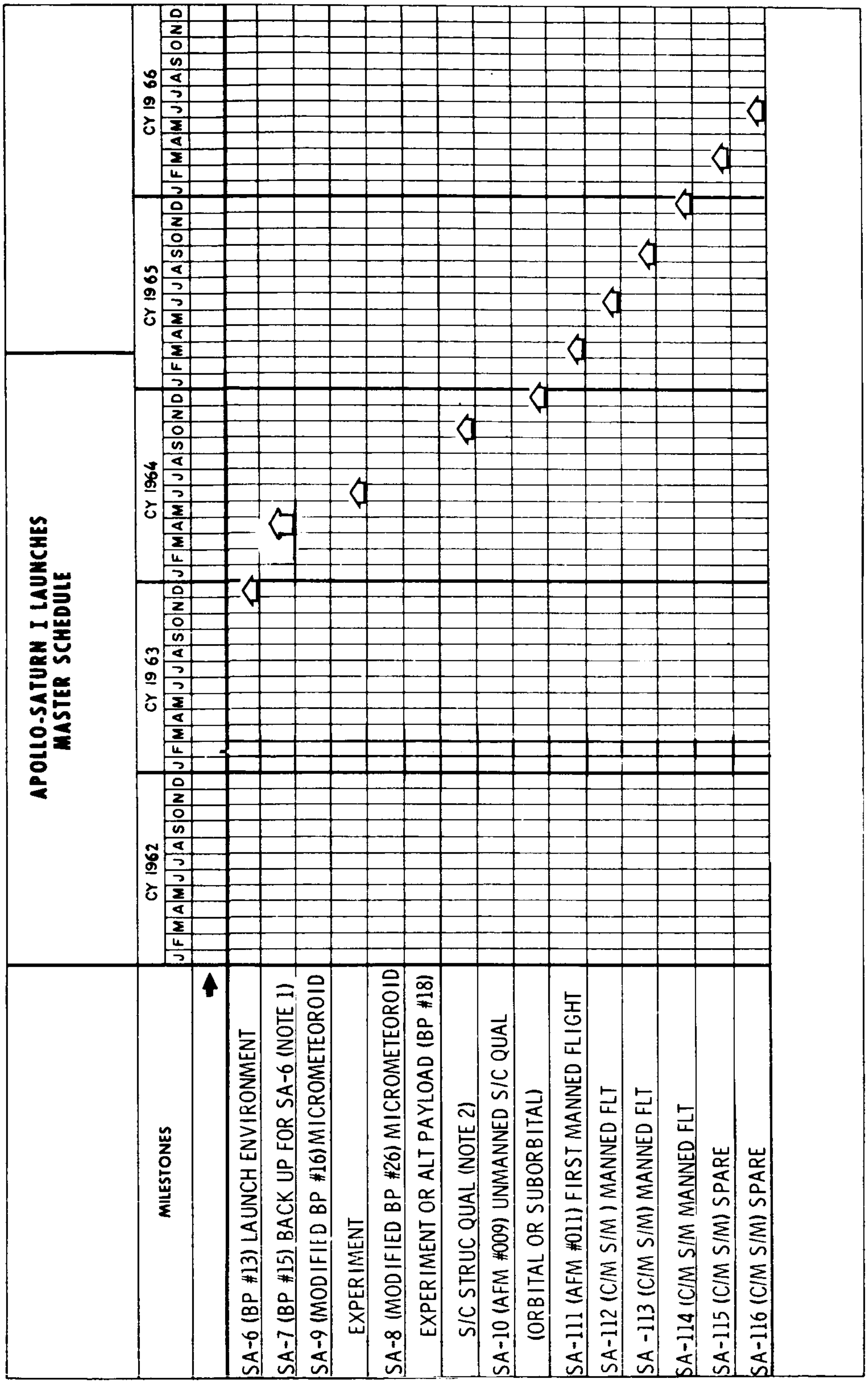

Figure 5 - Apollo-Saturn I Launches

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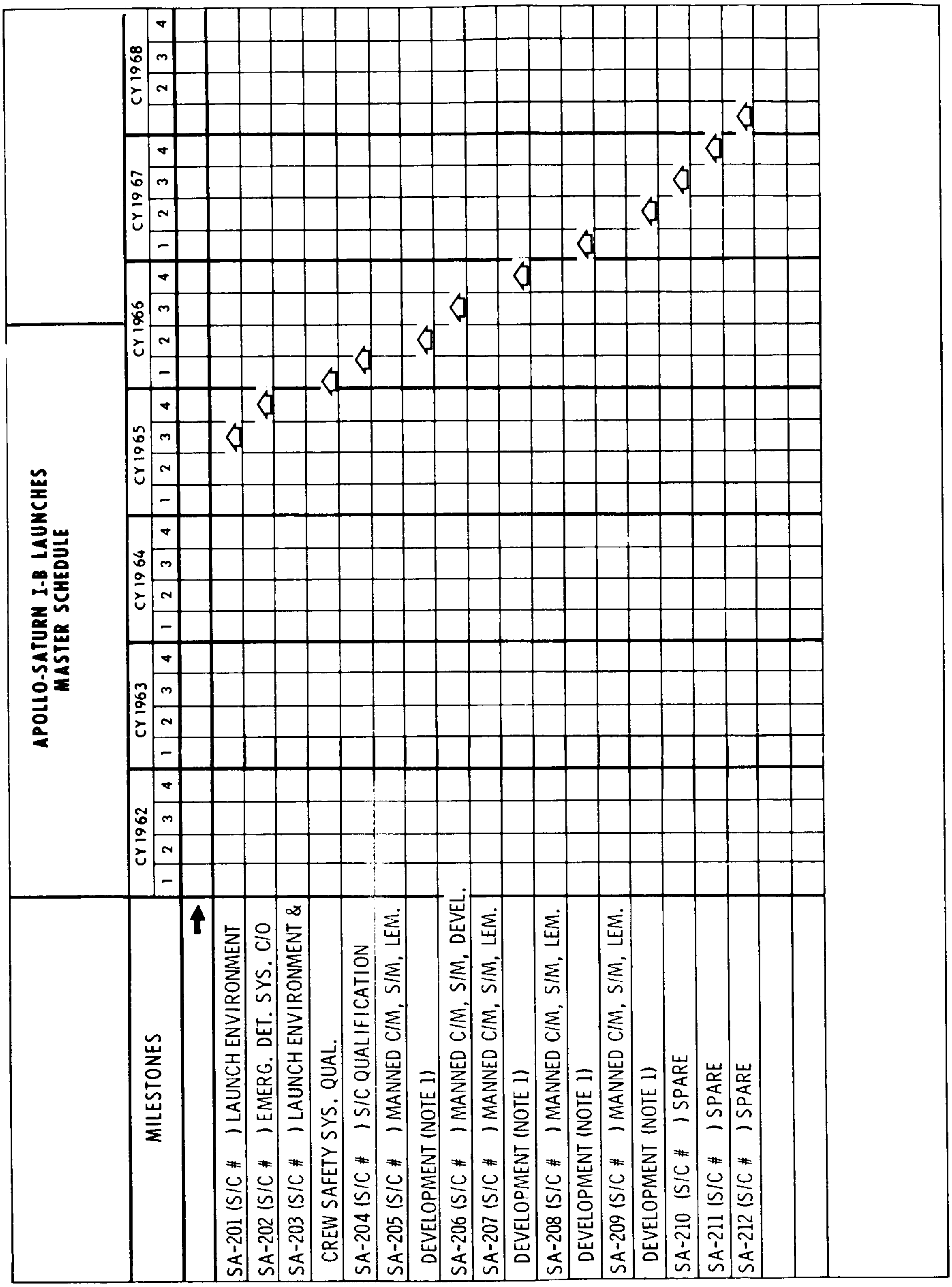

Figure 6 - Apollo Saturn I-B Launches

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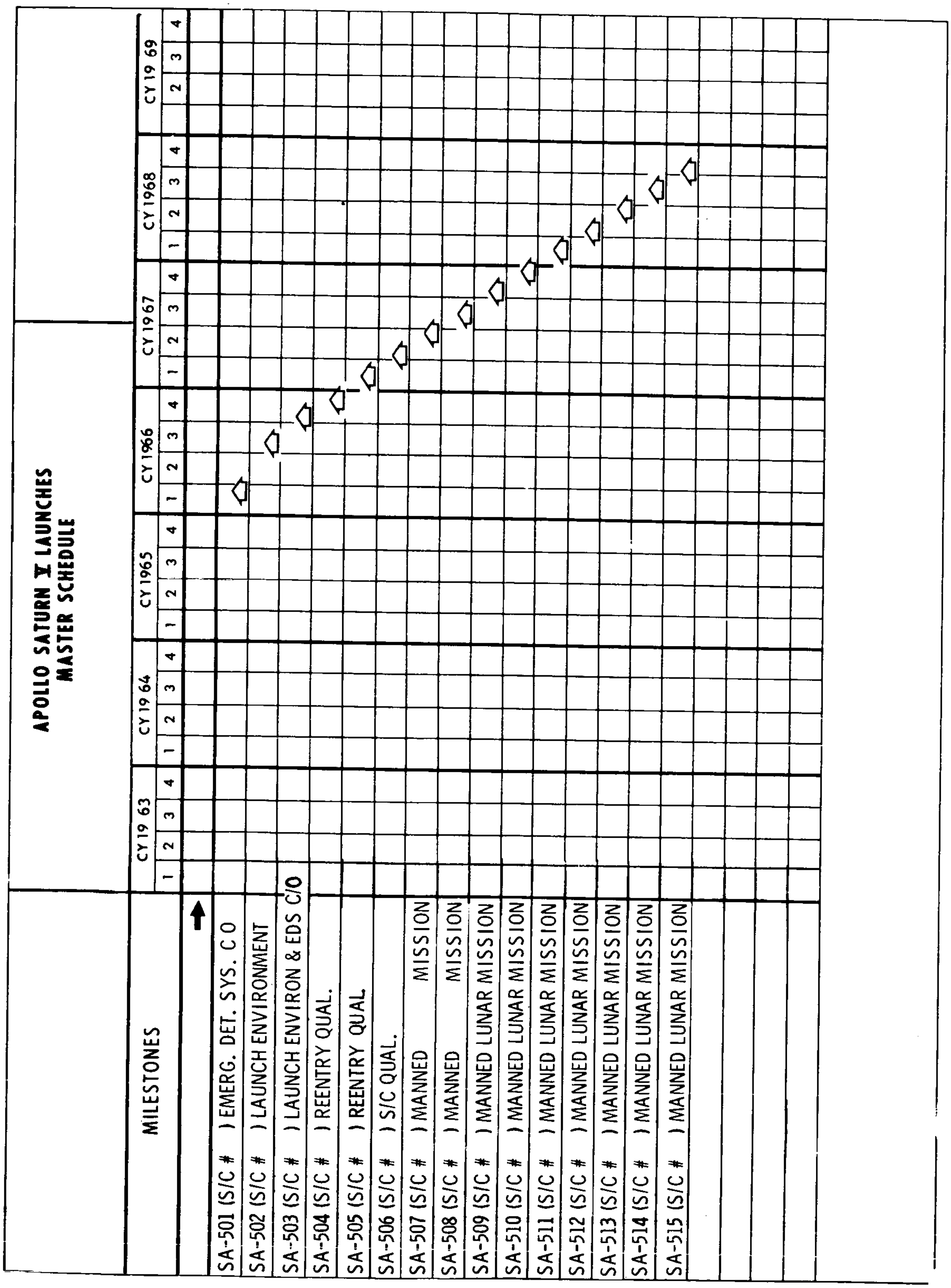

Figure 7 - Apollo Saturn V Launches

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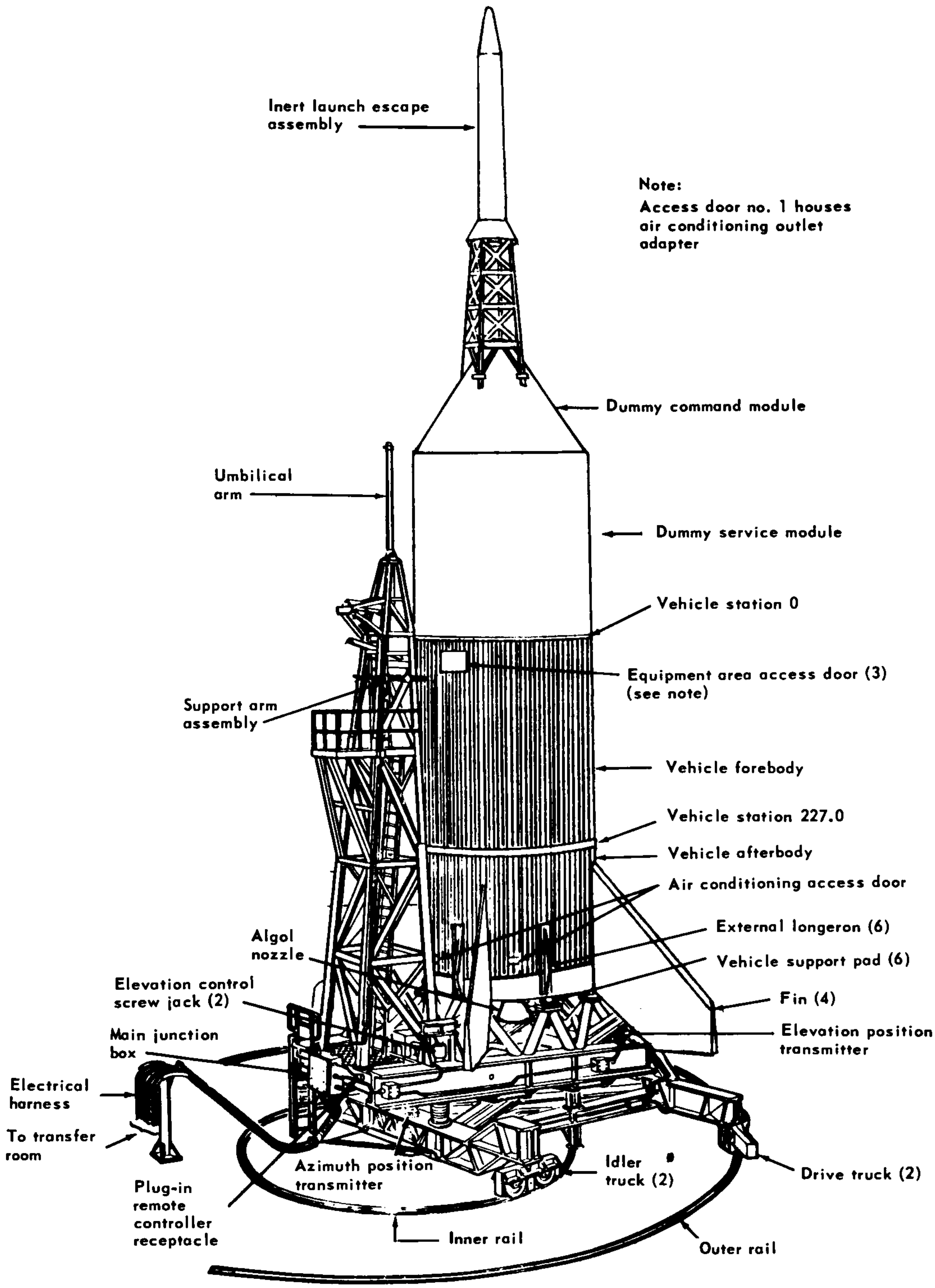

Figure 8. - Little Joe II Launch Vehicle and Launcher

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